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INVESTIGATION OF FLUTTER OF RECTANGULAR PLATE AT NON-ZERO FLOW YAW ANGLE

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Panel flutter is a phenomenon of self-exciting vibrations of skin panels of flight vehicles moving at high speeds. Usually panel flutter does not lead to immediate destruction of the aircraft, but results in the accumulation of fatigue damage of panels and the decrease of their lifetime. There are two types of panel flutter. The first one is the coupled-mode flutter, which is caused by the interaction of two panel eigenmodes. The second type is the single-mode flutter, in this case the coalescence of eigenfrequencies and a significant change in the oscillation mode shape does not take place.
The stability of the infinite series of thin elastic rectangular plates simply supported along all edges is investigated in this study. One side of the plate surface is exposed to a homogeneous supersonic flow of perfect inviscid gas. The other side experiences constant pressure so that the undisturbed state of the plate is flat. Due to connections between spans, plates are all either stable or unstable. The boundary layer is neglected. The non-zero flow yaw angle with supersonic leading edge is considered.
We use potential flow theory to derive expression for the unsteady aerodynamic pressure distribution over the oscillating plate. The plate motion equation, after the substitution of expression for unsteady aerodynamic pressure, is reduced to an integro-differential eigenvalue problem for finding complex eigenvalues. We use the Bubnov–Galerkin procedure to solve the eigenvalue problem. For the numerical solution of the frequency equation the iterative procedure is used. The sign of imaginary part of eigenvalue is the flutter criterion.
First, the convergence was studied and numerical parameters for flutter boundaries calculation were chosen. Results for zero yaw angle are correlated with those obtained previously by Shitov&Vedeneev (J. Fluids Struct., 2017). Next, flutter boundaries for the first eigenfrequencies were computed for non-zero yaw angles. Plates with different length and width were considered. Investigation has been conducted for Mach numbers from 1.1 to 1.7. We show how the single-mode and coupled-mode flutter boundaries are changed with the change of the yaw angle. Comparing with zero angle, new regions of instability appear that are caused by the interaction of three or more eigenmodes through the aerodynamic coupling.

ON EFFECTIVE VIBRATION SUPPRESSION OF SPINNING ROD

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The process of suppressing transverse vibrations of an elastic rod spinning in a horizontal plane and fixed at one of its ends is studied. It is supposed that the rod spins around the vertical axis at a constant angular velocity and performs transverse vibrations in the vertical plane, the vibrations are assumed small in amplitude. Transverse vibrations of the spinning rod are performed under external mechanical action. Lateral vibrations are described by the displacement function and considered in a rotating plane by using the classical beam model. The necessary conditions of optimality are derived and applied for suppressing elastic vibrations on a finite time-interval. The problem of optimal suppression of lateral vibrations caused by initial disturbances is formulated as a variational problem with constraints that take into account the suppressing effects on the rod. The limiting restrictions are presented in the form of inequalities. With the introduction of an additional variable, these restrictions are reduced to standard integral equality, while taking into account the energy constraints imposed on the control actions. The proposed iterative algorithm for solving the formulated problem is a numerical-analytical algorithm and consists in minimizing the quadratic quality criterion. This criterion characterizes the vibration suppression process and allows the implementation of improving variations. As a result of the operations carried out, the dependence of the vibration suppression process on the determining parameters, such as the angular velocity of rotation, the isoperimetric energy constant, and the length of the considered process of vibration suppression in time, has been clarified. An example that illustrates the implementation of the proposed algorithm and shows the effectiveness of this method for suppressing lateral vibrations is given.
This study is partially supported by the Ministry of Science and Higher Education within the framework of the Russian State Assignment under contract No AAAA-A20-120011690132-4 and partially supported by RFBR Grant 20-08-00082a.

EFFECT OF GROUND FURNACE SLAG ON AXIAL CAPACITIES OF CONCRETE-FILLED STEEL TUBES

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In the present study, sixteen circular concrete-filled steel tubular (CFST) columns were tested under axial compression to investigate the effect of the replacement of cement by ground furnace slag (GFS) on the ultimate load-carrying capacities of CFSTs under axial compression. Concrete mixtures with replacement level of 0, 15, 25 and 35% were prepared. Density and compressive strengths were also determined for all the concrete mixtures. Series 1 (Length/Diameter = 2.9) and series 2 (Length/Diameter = 4) of CFSTs with a Diameter/thickness of 45.84 were tested. Results of the experimental investigation indicated that enhancing the replacement of cement with GFS improved the concrete's workability and compressive strength but reduced the density of concrete. Ultimate load on the CFSTs were also improved as the quantity of GFS in the concrete mix was increased. Improvement in the load-carrying capacity of CFSTs was found to be proportional to enhancement in concrete compressive strength. The stiffness of the CFSTs did not change as the replacement level was increased.

SINGULAR SOLUTIONS IN PLASTICITY

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Solutions for several rigid plastic models are singular in the vicinity of certain surfaces. These surfaces are called maximum friction surfaces in the case of rigid perfectly plastic models. The friction stress on such surfaces is equal to the shear yield stress of material. In the case of the double shearing model and the double slip and rotation model, the singular surfaces are envelopes of characteristics. In all these cases, the quadratic invariant of the strain rate tensor follows an inverse square rule in the vicinity of the surface. Singular solutions also exist for anisotropic materials and viscoplastic materials. In the former case, the exact asymptotic representation of solutions depends on the shape of the yield surface. In the latter case, singular solutions exist only if there is a saturation stress (the yield stress approaches the saturation stress as the quadratic invariant of the strain rate tensor approaches infinity). The exact asymptotic representation of solutions depends on the dependence of the yield stress on the quadratic invariant of the strain rate tensor. Singular solutions allow one to introduce the strain rate intensity factor. This factor can be used for describing the generation of fine grain layers near frictional interfaces.

MECHATRONIC VIBRATION SETUP: EXPERIMENTS ON SYNCHRONIZATION AND CONTROL

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In the talk, the results of experiments on syncronization and contol, performed on the Multiresonance Mechatronic Laboratory Setup (MMLS) SV-2M of the IPME RAS are presented. It should be emphasized that Professor Blechman was among the initiators of the development of the stand, he outlined the range of its possible applications in research wokrs on vibration technologies, the mechanical resonance phenomena and oscillations synchronization. He had paid great attention to the works performed at the setup, actively participated in the discussion and helped with the interpretation of the experimental results, suggesting the directions for further research.

The MMLS SV-2M has been developed on the basis of many years of experience on creating vibrating stands at the Mekhanobr Engineering JSC and the IPME RAS. It includes the unbalanced vibro-actuators, mounted on the spring-suspended platform, sensors, electrical motors and the computer interface facilities. The stand can operate in two vibroactuator modes: the self-synchronization mode and the controlled synchronization} one. Using the vibroactuators self-synchronization phenomenon makes it possible to obtain various types of vibrations of the stand frame by changing the rotors turning direction. Experimentally, the areas of appearance of the self-synchronizations and the Sommerfeld effect are found.

In the talk, the experimental study of possibilities for control of the phase shift between two vibration actuators in the setup SV-2M. The Integral-Differential Speed-gradient control algorithms for control of the vibration fields by controlling the phase shift between rotors are proposed and the performance of the closed loop system is examined by simulation of the two-rotor mechatronic setup SV-2M. The various angular frequency and phase shift control algorithms

for SV-2M based on the PI-control and the consensus concept are proposed
and experimentally studied. It is shown that the closed-loop control makes it possible to stabilize the rotation speed more accurately, than it is possible in the case of the open-loop motors control. However, in the vicinity of the mechanical resonance, some additional effects, like low-frequency self-oscillations may arise due to the presence of the integral component of the control action.

THE EFFECT OF AGING ON THE CREEP PROPERTIES OF CARBON FIBER PLASTICS

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In recent years, various polymer composite materials become more widespread and developed. These materials are implemented in many areas of industry and construction, in particular, in aircraft, rocket and automobile construction, shipbuilding, railway transport, agricultural machinery production, as well as in the manufacture of sport equipment. Advantages of these materials: high strength and stiffness, lightness, high fatigue strength, chemical inertness, heat and electrical conductivity, and others.

These polymer composite materials are used in critical areas of engineering practice, so this makes their long-term aging, creep and fatigue characteristics of paramount importance. At the same time, the physical and chemical characteristics of these materials essentially changed after long-term operation, significantly due to the aging process [1-4]. Thus, investigations of aging of these materials are much needed.

Experimental studies on alternation of creep, cyclic loadings, climatic and thermal aging were conducted to study the evolution of creep characteristics of carbon fiber reinforced plastics (CFRP). Specimens made of unidirectional CFRP of the T107/ON190/P132436 brand with a working length of 140 mm, a width of 15 mm and a thickness of 0.8-1 mm we tested. Fatigue and creep experiments were carried out on a desktop fatigue servo hydraulic test machine Si-Plan SH-B and Tinius Olsen H10K-T tearing test machine correspondingly.

The experimental compliance curves for CFRP specimens after aging and after additional aging are received. For specimens after additional aging a hardening effect by more than 20% is occurred. To describe the compliance curves of CFRP specimens a modified version of the Maxwell equation written in the generalized time scale is used. The generalized time parameter in common case is able to describe the interrelated deformation and physic-chemical processes and define their development in the scale of deformation and chemical time. Theoretical compliance curves are plotted. A good agreement between theoretical and experimental compliance curves is observed.

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INFLUENCE OF AEROTHERMOACOUSTIC TREATMENT ON THE CHARACTERISTICS OF CASTING ALUMINUM ALLOYS

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The work presents the results of assessing the quality of cast aluminum alloys after aerothermoacoustic treatment in comparison with standard heat treatment of these alloys using the Ishikawa and Pareto diagrams, as well as the desirability function, quality web and correlation analysis.

Aerothermoacoustic treatment (ATAT) is one of the combined means of influencing materials. During its implementation, the effect of temperature and acoustic fields is carried out to form the properties of materials in the desired direction both in the entire volume and in the surface layer of the material. This work is devoted to the experimental study of the microstructure of aluminum alloys after aerothermoacoustic treatment in combination with standard heat treatment (SHT) in various combinations and the assessment of their characteristics after this treatment.

The materials for the study were aluminum-based casting alloys AL9 and ALA.

The indicated aluminum alloys were metallographically investigated after aerothermoacoustic treatment and, for comparison, after standard heat treatment. Microstructure studies were carried out on a Neophot-32 optical microscope on metallographic thin sections after chemical etching. Microhardness was determined by the Vickers method on a

PMT-3 device at a load of 20 g. To study the change in the structure of aluminum alloys from the surface to the center, panoramas of changes in the microhardness were taken from the surface of the microsection to the middle.
Alloy AL9 belongs to multicomponent silumin. To increase their mechanical properties, silumins are additionally alloyed. In particular, the AL9 alloy is alloyed by magnesium. Magnesium (Mg) forms a compound Mg_2Si with silicon (Si). It has high hardness and strength, and therefore is a hardener of the AL9 alloy. The alloy contains a small amount of Mg - up to 0.4%. Such a slight alloying with magnesium is due to its low solubility in solid aluminum (Al) at a temperature of heating for hardening (500-530^{0}C).
Alloy AL9 is a hypoeutectic silumin, the structure of which consists of primary crystals of a soft plastic phase - an α–solid solution and a fine-crystalline eutectic (α + Si). Despite the noticeable and variable solubility, silicon does not impart the ability to harden by heat treatment to aluminum, which is associated with the unfavorable nature of the decomposition of the solid solution of silicon (Si) in aluminum (Al). The introduction of Mg into the AL-9 alloy makes it thermally hardened. Magnesium forms the Mg_2Si phase, which is an effective hardener during heat treatment consisting of quenching and artificial aging. If the mass ratio in the ternary system Al-Si-Mg %Mg/%Si<1,73, then the alloy contains an excess of Si (in this case, the ratio is <0.1).
Alloy AL9 in the initial state is a cast dendritic structure of an α-solid solution of silicon (Si) in aluminum (Al) and eutectic along the boundaries of this solid solution. The strengthening Mg_2Si phase is located inside the grains of the solid solution.
The ALA alloy differs from the AL9 alloy in a higher content of silicon and iron and a lower content of magnesium. The structure of this alloy also represents grains of an α-solid solution of Al, along the boundaries of which the eutectic is located. With an increase in the Si and Fe content, the β (AlSiFe) phase is formed, which precipitates in the form of needles or plates.

EQUAL-STRENGTH DESIGN OF AXISYMMETRIC SHELL PENETRATING INTO CONDENSED MEDIA

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Problems of optimization of rigid shells moving in condensed media are important from theoretical and applied point of view. The strength of the moving shell becomes critical for some velocities and structural parameters of moving shells. For this reason, it is necessary to study safety cases and corresponding shell parameters. In this study, we apply analytical and numerical methods for this purpose. The model of axially moving axisymmetric thin shell subjected to external forces is used to describe the distribution of membrane forces. This is performed in context of dynamical behavior of the considered moving shell and, as a result, the critical stresses can be analyzed taking into account the velocity and strength parameters. The distribution of the shell thickness is found as a function of the problem parameters. Special attention of the study is related with the analysis of in-plane tension influence on the behavior of the shell strength. Then, we present detailed analysis (solution) for particular cases: spherical shells, conical shells, elliptic shells and others.
This study is partially supported by the Ministry of Science and Higher Education within the framework of the Russian State Assignment under contract No AAAA-A20-120011690132-4 and partially supported by RFBR Grant 20-08-00082a.

NUMERICAL STUDY OF ULTRA-HIGH-PERFORMANCE CONCRETE PARAMETERS IN RHT MODEL FOR PREDICTING THE RESPONSE OF CONCRETE PANELS TO BALLISTIC IMPACT

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The material behavior of concrete in extreme dynamic events like blast and impact requires the understanding of its dynamic characterization. There is ample research available on the study of quasi-static behavior of concrete, but quantum of research work on the prediction of dynamic response, specially under high strain loadings is still limited. Although number of material models are available for modelling the concrete's dynamic behavior, but this work focusses mainly on RHT model. RHT model includes elastic limit, failure, and residual strength of the crushed concrete under pressure. This leads to large number of material constants in RHT model. In this work Explicit Dynamic Software LS-Dyna is used to perform the numerical simulations and results from numerical simulations of a steel projectile penetrating an Ultra High Performance Concrete slabs are discussed. The study involves the verification of various RHT material constants on the penetration results i.e., residual velocity and damage pattern. Thus, numerical simulation results are, when possible, compared to experimental ballistic test done in 1992 by Hanchak et.al. Finally, the simulation results are summarized and concluded.

MULTISOLITON COMPLEXES IN CHAINS OF ACTIVE MORSE - VAN DER POL PARTICLES

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Nonlinear lattices have been actively studied for at least the last two decades. Interest in nonlinear lattices is due to the wide possibilities of modeling various periodic structures with their help, from atoms in crystalline bodies to flocks of insects, fish and birds. The variety of regular dynamic forms in nonlinear lattices expands upon passing to the consideration of active particles. The latter are capable of both dissipation and accumulation of mechanical energy when interacting with the environment. Traditionally, this interaction is modeled by introducing into the equation of motion a term corresponding in shape to the Stokes friction force, the friction coefficient in which can take both positive and negative values. The interaction between particles is determined by some form of elastic potential, for example, Toda or Morse. In this work, we study metastable multisoliton complexes in chains of particles, the forces of interaction between which are determined by the Morse potential. Active-dissipative forces are given in the Van der Pol form, which makes it possible to spatially separate the zones of dissipation and accumulation. The study showed that in such systems there are dissipative solitons propagating along a certain pedestal. Numerical modeling revealed the lower and upper boundaries of the pedestal, at which the soliton is formed and propagates steadily. The formation of a soliton occurs in an infinite chain or a chain with periodic boundary conditions by setting the simplest initial condition under which all particles are located at a given pedestal and have zero velocity, except for one particle, which receives some initial momentum. Dissipative solitons are resistant to small local perturbations of the pedestal and are capable of infinitely long motion along the chain. The interaction of solitons manifests itself in their attraction, leading to the formation of stable soliton complexes, the speed of which coincides with the speed of single solitons on the same pedestal. An increase in the number of solitons in the complex leads to an exponential increase in the sensitivity of the complex to small perturbations. This property makes it possible to control the number of solitons in the complex by the action on it of small perturbations of the pedestal. Approximate analytical models of the leading and trailing edges of a soliton allow to predict with high accuracy the amplitude and velocity of a soliton complex, as well as to substantiate the existence of pedestal boundaries, beyond which the soliton complexes are not capable of stable propagation. It is shown that the requirement for the positive work of active-dissipative forces at the leading edge of the soliton limits the allowed range of pedestals from below, and the upper limit of this range is determined by the bifurcation of the shape of the soliton trailing edge.
The reported study was funded by RFBR, project numbers 20-01-00123, 20-38-70158.

THERMODYNAMIC STUDY OF POLYETHYLENE CONTAINING MULTI-WALLED CARBON NANOTUBES

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The intense use of high density polyethylene (HDPE) in industry motivates scientists to give it a prominent place.
The objective of this work is to study the additions of multi-walled carbon nanotubes on the thermodynamic properties of HDPE.
The preparation of four samples PE + X% NTCM where (X = 0.01; 0.04; 0.07 and 10%) was done in a high energy mill.
According to the radial direction, the four curves have the same behavior. But, each one contains an anomaly located in the neighborhood of 145°C. Their intensities are similar except for the PE + 10% NTCM nanocomposites, where the peak is very intense compared with other three samples.
In the longitudinal direction, the four dilatometric anomalies are different. They are highly dependent on the concentration, but they all appear at approximately the same temperature. Dilatometric studies have shown that the measurements in the radial (R) and longitudinal (Z) directions are not the same. There is a significant anisotropy.
The calorimetric behavior of the four samples is closed, except for PE + 0.01% NTCM wherein the DSC curve is lower than the other three samples, over the temperature range. As for thermogravimetry, all the curves have the same behavior; the TG curves exhibit a very low weight loss over the temperature range.

COMPLEX SHAPE SEISMIC BARRIERS

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The paper will present the study of effect of seismic barrier geometric features on its protective properties. Different shapes of wave scatters as well as the effect of barrier material choice will be studied. The first results and methodology for utilization of neural networks for evaluation of optimal shape and materials for seismic barriers will be discussed. It will be shown that additional geometric features of seismic barrier can significantly affect barrier protective properties.

SOLUTION OF PROBLEMS ON DIE MOVEMENT ON SEMI-SPACE SURFACE ON THE BASIS OF NONLINEAR MODEL OF CRYSTAL MEDIUM DEFORMATION

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Problems of the die movement on the surface of the half-space are solved on the basis of a nonlinear model of deformation of a crystalline medium with a complex lattice [1,2]. Three speeds of the die movement are considered: subsonic, transonic and supersonic. For each speed of movement, the boundary problems are solved using the found general solutions of the dynamic equations of the nonlinear model of plane deformation [3,4]. Analytical solutions for stress tensor and displacement vector are obtained. In a nonlinear model, these values are determined by both the external influences on the medium and the optical mode. The optical mode plays the role of volumetric sources of the deformation and stress fields. Analysis of deformed and stressed states of the medium due to both the external impact on the medium and the optical mode was carried out. Analytical calculations are illustrated graphically.

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SURFACE WAVES IN ELECTRO-ELASTIC LAYERED STRUCTURES WITH IMPERFECT CONTACT AND SURFACE STRESSES

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The present work deals with two distinct models, Model I: Surface wave of anti-plane nature in an electro-elastic half-space with surface stress/elasticity and Model II: Interfacial wave at the interface between two electro-elastic half-spaces having imperfect contact and interface stress/elasticity. Gurtin-Murdoch (G-M) model has been adopted in order to consider surface and interface stresses. Closed-form expressions of new dispersive waves have been obtained and also possibility of B-G wave propagation has been studied which also validates the results. Since surface elasticity can be considered as thin film, Gold and Aluminium thin film have been considered for numerical computation. Significant effect of non-perfect bonding associated with mechanical stress and electric potential has been found. The present study may find its application in smart devices, such as Surface Acoustic Wave (SAW) devices related to the field of acoustic engineering, structural health monitoring, thin film technology, biomechanics etc.

COMPATIBILITY CONDITION AND DAMAGE SPREAD IN DENSE LATTICES

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The paper studies dense lattices in which the number of links exceeds the number of degrees of freedom of the nodes. In such lattices, the lengths of the links always satisfy additional compatibility conditions that are analogous to the compatibility conditions in continuum mechanics. We derive and analyze these conditions for infinitesimal and finite elongations and prove limiting theorems. The theory is applied to a quantitive description of a state of a multi-connected or partially damaged lattice, providing a measure of the degree of damage. We also study the spread of damage in lattices and suggest a design that prevent formation of a crack; instead, a damage reveals as a multiplicity of small disconnected defects. The results were obtained in collaboration with Michael Ryvkin (Tel Aviv University), Andrejs Treibergs and Predrag Krtolica (University of Utah).

HYBRID BARNES-HUT/MULTIPOLE FAST ALGORITHM IN VORTEX METHODS FOR 2D FLOW SIMULATION AROUND AIRFOILS

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Vortex methods of computational fluid dynamics is an efficient tool for solving some problems of incompressible flow simulation around movable and immovable airfoils, including FSI problems. Modern mathematical models of viscosity effect simulation in vortex methods are especially efficient in case of outer flow simulation. Vortex methods belong to a class of particle-based methods, where the particles are considered as vorticity carriers with long-range interaction. It leads to the *N*-body problem of mutual interaction calculation for all the particles. The corresponding algorithm has squared computational complexity, that restricts significantly the range of applicability of vortex methods.

In the present research the approximate tree-based algorithm of quasilinear computational complexity is suggested for performing of the main operations in vortex method algorithm. The main idea is that the influence of far-placed clusters of particles can be calculated approximately instead of direct point-to-point interactions calculation. The proposed fast algorithm combines ideas of the Barnes-Hut and the fast multipole (FMM) methods. Similar to the Barnes-Hut method, we perform the tree traversal, determination of the far and nearby placed particles clusters for each tree leaf cell, according to chosen proximity criterion, that allows adjusting the accuracy in a wide range. The far-placed clusters influence is replaced by its several multipole moments influence, similar to the original FMM algorithm. Unlike the classical Barnes-Hut algorithm, suggested approach deals with multiple particles per leaf cell, so the local expansions of the influence function for corresponding multipole terms are used in order to calculate velocities of the particular vortex particles.

The developed fast algorithm also can be applied for determination of the vortex sheet intensity that replaces the airfoil surface line influence on the flow and can be found from the boundary integral equation solution. For this purpose, the high-accuracy numerical schemes should be used. However, in the framework of the developed fast method usage, it is not required to calculate explicitly all the components of a matrix of the resulting linear system. Furthermore, the matrix-vector multiplication, that occurs at system iterative solution, can be performed approximately with quasilinear computational complexity.

As a result, the proposed fast algorithm is applicable for different operations in vortex method such as vortex particles velocities calculation, the boundary integral equation solution, velocity and pressure reconstruction at observation points and vortex wake reconstruction procedure. The fast method usage leads to significant speedup of the runtime per one time step and total calculation time. The total time step speedup depends on the current number of vortex particles and can reach up to tens-hundreds times in comparison to the direct calculation.

ELASTICA AND OSCILLATORY CONFIGURATIONAL FORCES

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Introduced by Eshelby [3] for describing the motion of inhomogeneities within solids, configurational forces have been recently shown to act on elastic rods constrained by frictionless sliding sleeves within both the quasi-static [2] and

dynamic [1] frameworks. These forces are found to be nonlinear, more specifically proportional to the square of the bending moment at the sliding sleeve entrance, parallel to the sliding direction and outward from the constraint.
The dynamic action of oscillatory configurational forces on the elastica is analyzed here by considering the harmonic motion of a sliding sleeve constraining an elastic rod within a gravitational field. The spatial-time integration of the corresponding moving boundary value problem is performed through an in-house developed Finite Element (FE) code. The dynamic response of the system is shown to be dramatically affected by three dimensionless parameters, defined by the oscillation amplitude and frequency of the constraint motion and by the gravitational field. The resulting motion in presence of (viscous and frictional) dissipation is observed to be characterized by three different behaviours, corresponding to a complete final injection, a complete final ejection, or a stationary motion.
These findings lead to new design principles ready to be exploited in actuation or dissipation mechanisms.

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PIOLA TRANSFORMATION OF STRESS AND DOUBLE STRESS IN SECOND GRADIENT CONTINUA

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Second gradient continua are continua with internal virtual work contributions that depend linearly and continuously on the first and second gradient of the virtual displacement. These virtual work contributions can be postulated either in Lagrangian (referential) or Eulerian (spatial) form and define respectively the Piola-Lagrange stresses as well as the Cauchy-Euler stresses. We show how the principle of virtual work in Lagrangian form emerge as a generalization of the minimum of potential energy and derive the Piola transformation of the appearing stress contributions. We give in both the Eulerian and Lagrangian description the expression of surface and edge contact interactions for second Gradient continua in terms of the normal and the curvature of contact boundary surfaces and edge shapes. Moreover, we formulate the complete boundary value problems in both representations.

BLAST IN THE ONE-DIMENSIONAL COLD GAS: FROM NEWTON TO EULER AND NAVIER-STOKES-FOURIER

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It is known that a gas composed of a large number of atoms following Newtonian dynamics can be described by the continuum laws of hydrodynamics. Proving this rigorously is one of the outstanding open problems in physics and mathematics. Surprisingly, precise numerical demonstrations of the equivalence of the hydrodynamic and microscopic descriptions are rare. The talk will discuss recent numerical tests of this equivalence in the context of the classic problem of the evolution of a blast-wave, a problem that is expected to be at the limits where hydrodynamics would work.

NONLINEAR BOUNDARY VALUE PROBLEM FOR CIRCULAR ELASTIC PLATE

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Mathematical modeling for finite deformations of thin membranes and plates is an essential part in the modern devices and technologies design, particularly for MEMS structures. However, the mathematical theory of such nonlinear problems is far from complete. There are currently a number of approximate methods using different assumptions and hypotheses.
This paper develops a method for modeling finite axially symmetric deformations of a circular plate which takes into account the specify of its additive manufacture.
The circular nonlinear membranes bending problem for first time has been presented and solved in a treatise of Green and Adkins. In their work, solution of inflating circular nonlinear membrane axisymmetric problem was reduced to solution of a boundary value problem for a system of eight ordinary differential equations with eight unknown's variables. Later, Yang and Feng proposed a method that allows reduce the system of eight governing equations to system of three ordinary differential equations and replace boundary value problem to initial value problem. The obtained solution has found wide application in science and technology, for example, based on this solution, Feng and Hallquist proposed a method for Mooney – Rivlin parameters identification for new materials based on an analysis of the surface shape of a circular thin membrane inflated by pressure.
The Yang and Feng solution was obtained for a thin Mooney – Rivlin membrane fixed on boundary and loaded by pressure. Yang and Feng has been assuming that Kirchhoff hypotheses are valid for this problem, but in practice this is not always right. When modeling a number of practically important processes, for example, the process of layer-by-layer surfacing in 3D printing, it is necessary to describe membrane surface shape, taking into account non-diagonal (shear) components of Cauchy – Green strain tensor.
In this paper, a system of governing equation for Mooney – Rivlin circular membranes bending problem are presented, taking into account non-diagonal components of Cauchy – Green strain tensor. The resulting system was solved by the shooting method with an initial approximation in the form of solving a linearized problem. An obtained result has been comparing with the results of Yang and Feng. It was concluded that the influence of the non-diagonal components of strain tensor on shape surface of membrane fabricated with additive manufacturing is significant.

DYNAMICS OF THE SIMPLEST KELVIN'S MEDIUM IN THE VICINITY OF A NONLINEAR EQUILIBRIUM

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We consider linear perturbations of the reduced elastic nonlinear simplest Kelvin's medium. Kelvin's medium is a medium consisting of infinitesimal rigid bodies with axial symmetry and finite dynamic spin. Each body point has three translational and three rotational degrees of freedom and can freely rotate about its axis of symmetry with a large angular velocity, but other rotations and displacements are finite. We consider reduced Kelvin's medium, i.e. a particular type of medium which does not react to the gradient of microrotation. Such a constraint yields in zero couple stresses. We consider the simplest variant of Kelvin's medium, where in the natural configuration all the spins are collinear, and the anisotropy is related only to the existence of the dynamic spin (i.e. to the fact that no stresses are caused by the proper rotation of body points). We suggest the nonlinear strain energy based on the Zhilin's system of independent strain tensors (with gradient of micro-rotation eliminated from the system), since this system gives us complete linear equations in the vicinity of the natural state.
We write down the equations for small perturbations of this medium near a nonlinear prestressed state. We analyse the influence of the prestressed state on the plane wave behaviour and stability of the medium for the case of physically linear but geometrically nonlinear medium and isotropic tension or compression. We compare these results with dispersion relations for the simplest linear reduced elastic Kelvin's medium in the vicinity of natural state, which, as it was shown in previous studies, is a single negative acoustic material for a certain type of shear-rotational waves, polarized in the direction opposite to the spin, in some frequency domain.
The exact analogy between Kelvin's medium and ferromagnetic elastic insulators, established in earlier works, indicates that these results may have an application in the theory of magnetoelastic materials. Considering the reduced variant of Kelvin's medium, we neglect exchange interactions. Changing the stress state of the medium, we may partially control the the effective dynamic properties of the medium.

NUMERICAL ANALYSIS OF RAYLEIGH WAVE INTERACTION WITH SEISMIC BARRIERS AND PILE FIELDS TAKING INTO ACCOUNT THE ELASTO PLASTIC BEHAVIOR OF SOIL

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Vertical seismic barriers such as trenches, underground walls, pile fields etc. can be used as a mean of seismic protection from Rayleigh waves of various nature. The effectiveness of this approach confirmed by both theoretical studies e.g., the ones conducted by S.V. Kuznetsov, Bo Qui, as well as by experimental works for example, the studies of Barkan, A. Alzawi and MH El Naggar, etc. According to the obtained results, the so-called "shadow zone", where vibration decay can be observed, is formed beyond such barriers. Nevertheless, most of these studies were carried out for the cases of linearly elastic or viscoelastic materials. However, such approach may be adopted only for the vibrations that cause insignificant shear deformations that do not exceed 0.00001 during their propagation in the soil. At the same time, shear deformations in soils under seismic and explosive excitations can be equal to 0.001 or even more. Meanwhile, at this deformation level soil behavior is no more linear and can be described by elastic plastic constitutive equations. Thus, to assess the effectiveness of vertical barriers as a mean of protection against Rayleigh waves generated by earthquakes, it is necessary to use at least elastic-plastic models to describe soil behavior more accurately. In that case, it is possible to simulate the formation of plastic zones during the interaction of seismic waves and barriers. In this work, Mohr Coulomb model is used as it is most widely used in soil mechanics and has a large database for characteristics of various soils.
Based on numerical simulation of interaction of vertical barriers and Rayleigh waves accounting elastic plastic behavior of soils, the influence of soil plastic properties on the effectiveness of these protection approach is assessed. In addition to that, applicability of vertical barriers against Rayleigh surface waves at high strain level in soils is analyzed to identify the possible measures that can improve barriers efficiency in terms of vibration protection and expand the area of their applicability.

INTERDIFFUSION DESCRIPTION AT ELASTIC BODY WITH MICROSTRUCTURE CHANGING BY MARKER APPROACH

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A description is adopted that combines the balance equations for an effective continuous medium with the component mass balance equations. The marker method, as an approach describing a diffusion phenomenon, is chosen. It has certain advantages compared to the material and spatial methods. These approaches differ in the definitions of the continuum element and component flows, and, being theoretically equivalent, allow us to set certain types of problems more or less naturally. The marker approach proposed by G. B. Stephenson defines a continuum element as a tightly packed macroparticle (a marker), which is a thermodynamically open system. Thus, a certain elementary volume is able to change an atomic composition. It makes convenient to construct equations of state (the configuration part of the chemical potential in the framework of statistical thermodynamics). The state variables are the volume concentrations and the diffusion fluxes are independent.
The balance and constitutive equations of the system being considered are written out for studying the relaxation time spectrum near a homogeneous stationary solution of the problem of layer transverse compression. Part of these relaxation times is mathematically related to diffusion processes and in this analysis is associated with the characteristic times of these processes in a coupled system. The resulting eigenvalue problem allows us to obtain analytical expressions for interdiffusion coefficients in a coupled system and to investigate their asymptotics at infinitesimal and infinitesimal wavelengths of solution spatial perturbations. Mathematical analysis of these coefficients shows that in a fine grain structured medium their values significantly exceed the self-diffusion coefficients. It correlates with the experiment results.

MULTISCALE MODELING: MODELING SUBGRID EFFECTS AND TEMPORAL SPLITTING

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In this talk, we will start with some main concepts in multiscale modeling including numerical homogenization and multiscale finite element methods. Our goal is to model processes in multiscale media without scale separation and with high contrast. We assume that the coarse grid doesn't resolve the scales and the contrast. To deal with these problems, I will introduce multiscale methods that use multicontinua approaches. These approaches use additional macroscopic variables. I will discuss the convergence of these approaches and show that these methods converge independent of the contrast. The multicontinua approaches can benefit from machine learning techniques, which I will discuss. I will also consider how multiscale methods can be used for temporal splitting. High contrast brings stiffness to the system, which requires small time steps. We will introduce partial explicit methods that construct time discretizations with the time stepping that is independent of the contrast. Numerical results will be shown to back up our theories.

CALCULATION OF THE LATTICE DEFORMATION TENSOR FOR DO3-18R MARTENSITIC TRANSFORMATION IN CU-AL-BE SHAPE MEMORY ALLOY

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Shape memory alloys (SMA) of system CuAlBe are characterized, among other Cu-based SMAs, by relatively low temperatures of martensitic transitions, high mechanical strength, corrosion stability and advanced fatigue failure resistance. For the effective use these materials, models are needed allowing to adequately calculate deformation at different thermal and mechanical conditions. One of the most important material constants of the microstructural model used in this work is the lattice deformation tensor for DO3-18R martensitic transformation of the initial high-temperature austenite phase into a low-temperature martensitic phase. The calculation of the deformation tensor matrix for the CuAlBe SMA was performed. Matrices of strain gradient and Green-Lagrange tensors were calculated based on X-ray data for the lattices parameters of austenite and martensite. The resulting matrix of the deformation tensor was used to simulate the functional and mechanical properties of this material, including cyclic thermomechanical loading. The data obtained are in good agreement with the available experimental results.
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ON THE ANTICLASTIC BENDING OF SOLIDS AT FINITE STRAINS

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The present work deals with the problem of compressible isotropic hyperelastic solids under finite bending. The problem is fully nonlinear and, conversely to the classical Rivlin solution [1], it is formulated in the framework of three-dimensional kinematics involving both large displacements and strains according to the context of finite elasticity. The model entails three kinematic assumptions, which stand for the planarity of the cross sections (Bernoulli-Navier hypothesis), the invariance of the curvature along the longitudinal direction of the solid (uniform bending) and the curvature of the cross sections (anticlastic curvature), that is assumed constant along the width of the solid [2]. Based on the semi-inverse approach and according to the kinematic assumptions, the 3D displacement field is found, and, in turn, the deformation gradient is assessed. Then, the equilibrium conditions, specialized for a compressible Mooney-Rivlin material, provide proper relations among the unknown kinematic parameters, thus leading to the closure of the problem. Emphasis in placed on the "moment-curvature relation", which is found to be governed by two independent dimensionless parameters: the *Eulerian slenderness* and the *compactness index* of the solid cross sections [3]. Similarity is observed with respect the previous works of *Lamb* (1890) regarding the mechanical response of bent plates and the experiments performed by *Searle* (1933) as well. Moreover, such an analysis allows broadening the "Elastica" to the more general context of finite elasticity.
In this work, the main results provided by the theoretical model are compared with those obtained by FE simulations and an experimental investigation based on a specifically designed mechanical apparatus, founding good agreement also for the case of extremely inflexed solids.

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NUMERICAL INVESTIGATION OF THE DROPLETS DYNAMICS IN MICROCHANNEL WITH HYDRODYNAMIC TRAPS

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Nowadays, many industries require the application of new effective technologies that can be developed based on fundamental research in microfluidics. The three-dimensional simulation of fluid flow in complex domains is important for manufacturing of lab-on-a-chip devices, used, for example, to study multistage biochemical processes. Furthermore, microfluidic devices are widely used in biophysics, biochemistry, and medicine to perform chemical reactions as well as for precise manipulations of particles in the flow, such as focusing, separation, and fractionation. One of the critical problems in this field is the selection of optimal geometrical parameters in the design of different types of microfluidic devices for studying, including biological micro-objects and conducting sorting (separation) of particles, fixation of particles, cultivation of biological objects (cells, bacteria, etc.), preparation and processing of samples. The influence of structure geometry is actively reviewed by research groups, both from an experimental and theoretical point of view.
The present study is dedicated to the problem of viscous fluid flow with deformable droplets in microchannels with different types of hydrodynamic traps. All processes are considered at low Reynolds and moderate Strouhal numbers. Thus, the fluid flow is described by the stationary Stokes equations. The numerical approach is based on the boundary element method (BEM) for 3D problems accelerated both via an advanced, scalable algorithm (FMM), and via utilization of a heterogeneous computing architecture (multicore CPUs and graphics processors). To solve large scale problems flexible GMRES solver is used. One of the features of BEM is that it is well applicable for solving three-dimensional problems with free boundaries and is well suited for describing complex dynamics of particles with arbitrary deformation in the domains with complex geometry, as well as in shear flows.
The dynamics of droplets in microchannels and the influence of droplet characteristics on the flow around hydrodynamic traps were studied. Qualitative triangulation of microstructures with flat smooth walls with complex internal geometry, including arrays of hydrodynamic traps for fixation the deformable particles in the flow, was developed. Traps are consisted of nondeformable cylindrical elements with different spatial arrangements in microchannel. Investigations of hydrodynamic flow patterns in microstructures with traps of different configurations are carried out. The droplet dynamics in microstructures for several viscosity ratios and droplet sizes were investigated.

RESIDUAL STRESSES IN A THERMO-VISCOELASTIC ADDITIVELY MANUFACTURED CYLINDER SUBJECTED TO INDUCTION HEATING

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Additive manufacturing is considered to be one of the most promising industrial technologies of the near future, due to the fact that it allows creating three-dimensional metal parts of complex geometric and lighter weight shapes as well as multimaterial parts. The main theme is that the part is being created sequentially, layer by layer, due to melting and fusing metallic powders together in precise geometric shape.
There are some challenges that obstruct the practical application of these techniques. One of them is that, the metallic powders are heated to the melting temperature and then cooled when they are already attached to the part, which causes distortion of its geometric shape and the accumulation of residual stresses in it.
There is variety of ways to reduce residual stresses intensity in manufactured parts, most use the modulation of melting beam or heating of the part during additive process. These allow to reduce the inhomogeneity of temperature field and consequently to reduce residual stresses.
In present work we developed a mathematical modeling of temperature field and residual stresses that appear in additively manufacturing part. We also propose to heat the part during process in specific non-uniform manner which

upon the technological (melting) heating results in almost constant temperature profiles and hence in low residual stresses. To generate such specific heating one can apply an induction with high frequency current, modulated in time.
The mathematical model for thermoviscoelastic conducting growing cylinder is developed, with account of the damping factor related to the viscose properties of the material. The modeling of additive process is based on the idea of the sequence of boundary-value problems which describe elementary steps. The initial data for the boundary value problem for each step of the process are determined by the values of the corresponding fields at the end time of the previous step. The process of growth is considered as a sequence of thin cylindrical layers which are added one by one to the body, whose temperature is close to the melting degree.
Closed-form solutions are constructed for the half coupled and fully coupled thermoviscoelastic problems. The temperature field on the growing surface is analyzed numerically for various accretion scenarios.

SYSTEMS WITH PARTIALLY STRONGLY DAMPED VARIABLES IN ENGINEERING: FROM SOMMERFELD EFFECT TO ESCAPE DYNAMICS

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Capturing into the nonlinear resonance of an unbalanced rotor mounted on an elastic carrier system and excited by a DC motor was described by Arnold Sommerfeld as an experimental observation 1902. However, it took more than 50 years before Ilya Blekhman explained this effect (1953). His approach implicitly utilised several assumptions concerning relationships between different groups of parameters both in mechanical and electro-magnetic subsystems. For example, he used the “static” characteristics of the DC motor which means that the electric resistance is the dominating electric load. On the other hand, he supposed, that in the unperturbed state the rotor speed is constant and used the pure forced solution for the oscillations of the carrier system. Note that neither averaging nor singular perturbation techniques were established at that time. From today’s perspective both approximations can be justified as asymptotic approximations in a system with partially strongly damped variables. Mathematicians would describe them as non-critical fast variables.
The main application area of this approach in engineering was established by Blekhmans scholar K.Sh. Khodzhaev in his works on electro-mechanics. Many other applications appeared recently. In this talk we present several examples of the partially strongly damped systems, which were investigated in the last 5 years by the Blekhman’s scientific “great-grandchildren” at the Karlsruhe Institute of Technology. Starting with the non-stationary capture by and passing through the resonance of the unbalanced rotor with the attached self-balancing device we continue with the escape from the resonance of the self-synchronized vibration exciters. Blekhman’s results on the smoothening of dry friction under the high-frequency excitation can be significantly improved by taking the contact compliance into account. The corresponding model also contains strongly damped variables. Dynamics of hydraulic valves is strongly non-linear die to the typical non-smooth square root flow characteristics of the control edges. But the careful analysis enables to identify strongly damped variables in such systems also providing significant advantages both in the analysis of the system’s stability and in the design of an appropriate control strategy. Finally, the escape of a couple of particles from a potential well can be investigated with the same methods. Such problems appear in MEMS, where the surface related forces (damping) are dominant related to the volume related ones (inertia).
Summarizing, we demonstrate a wide spectrum of applications, where the Blekhman’s physically motivated approach gives rise to better understanding of non-linear behaviour and to improved technical solutions.

EFFECT OF HYDROGEN EMBRITTLEMENT ON THE TORSIONAL VIBRATIONS OF A THIN-WALLED TUBE

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The problem of oscillations of the systems containing pipelines is one of the actual problems of modern techniques. Hydrogen embrittlement of metals is a common cause of damage to pipelines, drill strings and equipment. Hydrogen is captured by crystal lattice defects, reducing plasticity and Young's modulus of metals. It is important to estimate the parameters of vibrations and acoustical fields of such objects in order to provide the construction from damaging, but calculation of these complicated systems demands major computing resources. Therefore the consideration of simple model problems which have exact analytical solution is actual. This paper studies the effect of hydrogen corrosion on the torsional vibrations of a cylindrical tube, which is modeled by a shell according to the classical Kirchhoff-Love theory. The weakening of the material under the influence of hydrogen is taken into account by introducing an elastic modulus averaged according to a certain law for the multilayer tube. The analytical calculations were supplemented with finite element calculations in the Ansys software. Formulas linking the change of natural frequencies with the parameters of the tube weakened by hydrogen corrosion have been obtained. They can be used to establish the degree of tube wear as a result of hydrogen embrittlement.

MODELING OF GRANULAR MEDIA GRINDING PROCESS WITH A VARIABLE VISCOSITY COEFFICIENT

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In this work, the solution to a coupled flow problem for a granular medium undergoing grinding is presented. The griding process occur due to moving of granular media through a funnel shaped crusher. The standard macroscopic equations for mass and linear momentum are solved in combination with a balance equation for the microinertia tensor containing a production term. This production term is responsible for the grinding description. The constitutive equations of the medium describe a linear viscous compressible material with a viscosity coefficient depending on the characteristic particles diameters. A coupled system of equations is presented and solved numerically in order to determine the velocity, pressure, viscosity coefficient, and microinertia in all points of the funnel shaped crusher. That means that a coupled problem is analyzed, in which the moment of inertia and the viscosity coefficient can change from position to position. The solution was found numerically using Finite Volume Method and the Upwind Scheme. The solution was realized in C ++ programming language.

VIBRATION AND CONTROL: INSPIRED BY ILIYA IZRAILEVICH BLEKHMAN

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I.I. Blekhman made a number of outstanding contributions into fundamental knowledge of complex mechanical systems. He created the whole new fields of science: vibration mechanics, vibration rheology, synchronization theory of dynamical systems and others. He developed the method of direct separation of motions based on the ideas of P..L. Kapitsa and turned it into a versatile tool. However, with these remarkable achievements, his contribution to science is not exhausted. Ilya Izrailevich had an amazing gift to get carried away with scientific problems and to captivate others with them, to see new promising ideas at the earliest stages of their inception and thus contributed to the development of new scientific directions simply by his very interest in them.
My talk is devoted to one of these areas, namely to the field related to vibration control, or more broadly, to control of oscillations. The origin of an approach to oscillation control based on the solution of excitation and synchronization of oscillations in nonlinear controlled systems by the speed gradient method is described.
The new tasks proposed for solution by I. I. Blekhman are listed: control of the passage of mechanical systems through the resonance zone and control of the phase shift between the vibroactuators, as well as the problem extracted from the works of I.I.Blekhman: control of vibrational fields.
The joint work on a general definition of synchronization, as well as joint development of educational and research mechatronic vibration stands is addressed.

BOUNDARY LAYER FORMATION DUE TO THE STRESS-INDUCED DIFFUSION IN MICROPOLAR MEDIA

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Standard hydrogen saturation of metal samples in an electrolyte or under cathodic charging can result in a highly nonuniform distribution of hydrogen across the specimen. As a result, almost all hydrogen due to the artificial saturation is accumulated within a boundary layer of about 60 microns. A local increase of hydrogen concentration can lead to hydrogen damage so that estimation of the distribution of hydrogen in a host material is of great interest.
The present research considers the stress-strain state of the host material as the reason for the inhomogeneous distribution of hydrogen. In order to model the size effect, we refer to the generalized continuum theory introduces intrinsic length scale parameters. The micropolar theory is chosen since it accounts for rotations of grains that are

observed in real experiments. The model accounts for the mutual influence of the inner stresses and strains and dissolved hydrogen. The influence of inner stresses and strains, in turn, is due to the dependence of the diffusion coefficient on the local elastic energy and due to the driving force in the diffusion equation. This model allows to relate the inhomogeneous distribution of hydrogen with a nonuniform stress-strain state of the material.
The theoretically obtained boundary layer contains all the dissolved hydrogen, whereas the experiments predict a deeper penetration of hydrogen. Thus, the model describes the skin effect, but a more complex diffusion process should be considered to account for the specific hydrogen transport. Moreover, within the frame of the present research, we also discuss different yield functions generalized for the case of the micropolar continuum and show that plastic deformations can arise near the border, while the material continues to behave elastically. Accounting for these deformations can, in turn, change the concentration profile. At the same time, theoretically estimated average concentrations of hydrogen obtained on the base of the micropolar hydrogen-elasticity model coincide with experimental data.
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BUBNOV-GALERKIN METHOD IN COMPUTATIONAL SOLID MECHANICS, A POSTERIORI ERROR ESTIMATES AND ADAPTIVE ALGORITHMS

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The role of the method, which in Russian publications in the area of Computational Solid Mechanics is related with names of two famous mechanicians I.G. Bubnov and B.G. Galerkin, is difficult to overestimate. Biographies of both authors are closely related to the history of the Polytechnic Institute in Saint-Petersburg [1]. In this presentation, we consider important mathematical aspects of the method [2] and its relation with such interesting topic of modern computational mathematics as error control and adaptive algorithms (see, for example, [3, 4, 5] and references therein).

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STABILITY, INSTABILITY STUDY AND CONTROL OF AUTONOMOUS DYNAMICAL SYSTEMS BASED ON DIVERGENCE METHOD

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A novel method of instability and stability of equilibrium points of autonomous dynamical systems using a flow and divergence of the vector field is proposed. A relation between the method of Lyapunov functions, Gauss (Ostrogradsky) and Chetaev theorems with the divergence conditions is established. The generalizations of Bendixon and Bendixon-Dulac theorems about a lack of periodic solutions in arbitrary order systems are considered. The state feedback control law design is proposed based on new divergence conditions. Examples illustrate the efficiency of the proposed method and the comparison with some existing ones.

STUDY OF AN EMULSION UNDER THE ACTION OF AN ELECTRIC FIELD IN THE PRESENCE OF A HYDRODYNAMIC FLOW

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The great interest in studies of emulsions under the action of an electric field is associated with the widespread use of dispersed systems in the form of liquid - liquid in various industries. One example is the oil industry, where there is a problem with the separation of persistent emulsions. And one of the promising methods is the use of an electric field of

different frequencies. Work on the separation of emulsions using microwave (MW) and radiofrequency (RF) EM fields is mainly associated with thermal action on the aqueous phase and on the polar components of oil, respectively. At the same time, the impact in the low-frequency (LF) range is associated with the occurrence of a dielectrophoretic force, which makes the droplets move in the region of a higher electric field strength. As a result of these judgments, the use of an LF electric field may be more applicable for separation problems.
This work is aimed at studying an emulsion under the action of an inhomogeneous electric field in the presence of a hydrodynamic flow. The object of research is a water-in-oil emulsion. Research is carried out in an experimental cell, which is a Hele-show cell formed by two glass substrates. A saw tooth microelectrode system is made on the lower substrate. A bipolar voltage is applied to the electrodes through a signal generator with subsequent amplification through an amplifier. The flow of the emulsion in the cell is created using a syringe pump. The exposure process is recorded on a high-speed camera.
After exposure, the volume of the exfoliated aqueous phase is estimated. Based on the research results, the dependences of the volume of the aqueous phase on the volumetric flow rate of the liquid and on the flow rate are constructed. The results can be useful for improving existing emulsion separation technologies or creating new combined methods.
The reported study was funded by the grant of the Russian Science Foundation (project No. 19-11-00298).

STRESS FIELD RECONSTRUCTION IN LAYERED ROCKS BY USING THE DATA ON PRINCIPAL STRESS ORIENTATIONS

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In this study we consider the problem of stress field reconstruction based on the WSMP (World Stress Map Project) data on principal stress orientations in the earth's crust. We generalise the earlier developed algorithms for plane elastic isotropic media to a 3D case of inhomogeneous rocks composed of the horizontal layers with different elastic moduli. It is assumed that the stress and displacement vectors are continuous across the interfaces between the layers and the vertical stress is always one of the principal in-situ stresses. It is shown that the principal stress directions in the horizontal plane are also continuous across the contour. We have also found the relationships between the stresses averaged over the whole thickness of the rockmass and those averaged over a single layer. These relationships make it possible to use the earlier developed methods for the stress reconstruction in elastic homogeneous plate in order to calculate the stress field in the upper layer of the earth's crust. The later is important for the development of earthquake protection methods.
Several models for the stress field reconstructed in the region surrounded the Taiwan Island have been developed. These use the WSMP data only without any hypothesis on the boundary stresses or displacements. It is shown that the vertical stress essentially affects the horizontal stresses at deep depth and can qualitatively change the stress trajectory field in lower layers as compare to upper layers.

FEEDFORWARD OPTIMAL CONTROL WITH CONSTRAINTS FOR A CYLINDRICAL THERMOELECTRIC SYSTEM ACTUATED BY A PELTIER ELEMENT

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In this work, we consider a cylindrical structure consisting of two heat conducting cylinders with a thermoelectric converter (Peltier element) between them. A control-oriented nonlinear model, which was previously proposed and verified by authors, is used to design an optimal control that allows to achieve a steady-state distribution of temperature in one of the cylinders in much less time than the characteristic time of transient processes. On the first step, the boundary value problem is exactly linearized about temperature distribution by means of feedback linearization. Although the resulting system is nonlinear with respect to a control function, it is possible to construct a finite-dimensional approximation based on analytical solution of corresponding eigenproblems for a constant control signal. After that, an optimal control problem with constraints over finite time horizon is solved numerically using this eigenfunction decomposition. We consider a cost functional that represents minimization of temperature deviation from the steady-state, minimization of energy losses and a penalty for violating the constraints. The finite time interval is split into several parts and on each subinterval the control signal is taken constant. The optimal piecewise constant feedforward control is found partially numerically by applying the gradient descent method and partially analytically by using the eigenfunction expansion. The resulting control is taken as a sum of feedback linearization and feedforward signals. We present numerical results and compare the proposed control with the optimal feedforward control without constraints.

NUMERICAL AND EXPERIMENTAL INVESTIGATION OF ELECTROHYDRODYNAMIC FLOW CURRENT CHARACTERISTICS FOR DIFFERENT ELECTRODE CONFIGURATIONS

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High voltage applied to a system of electrodes and liquid dielectric develops an electrohydrodynamic (EHD) flow. It is a perfect example of direct conversion of electric energy into kinetic energy. The phenomenon is highly promising as it can be used in pumps, cooling systems, 3D printers, injectors, soft robotics and so on. Yet designing and computer engineering of EHD devices is hindered by the lack of data on electrophysical parameters (mobility and injection function). Although injection function estimation technique exists, applicability of injection function fitted for one system was never verified for another (with unchanged electrode material and liquid). Therefor the work investigates dependency of injection function on electrode geometry.

The experimental study and the computer simulation of integral current characteristics are involved. Electric current was measured by so-called DCVC (dynamical current voltage characteristics). Computer simulation model solves the complete set of EHD equations using COMSOL Multiphysics software package. The data are analyzed and interpreted in terms of degree of conformity between the experiment and simulation. Unique plane-six wires-plane electrode configuration was used in experimental cell.

Reproducible and clean current characteristics were obtained for transformer oil and two nichrome wires with 100 and 35 mcm diameters. Comparison between experimental and numerical DCVC gave a good agreement within 15% measurement accuracy (current maximum in experiment – 100 nA, simulation – 85 nA). It was concluded on the effect of ion mobilities and interelectrode gap change on final current.

KAPITZA THERMAL RESISTANCE IN LINEAR AND NONLINEAR CHAIN MODELS

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Kapitza resistance in the non-homogeneous chain models is considered. For the case of the linear chain, the exact analytic solution for the boundary resistance is derived for arbitrary linear time-independent conservative inclusion or boundary. Contrary to the bulk conductivity in the linear chain, the Kapitza resistance is finite. However, for the case of the isotopic defect the universal thermodynamic limit does not exist. In other terms, the exact value of the resistance is not uniquely defined, and depends on the way of approaching the limit. By this reason, and also due to the dependence on the parameters of the thermostats, the resistance cannot be considered as a local property of the defect/boundary. Asymptotic scaling behavior of the heat flux is explored and compared to the nonlinear counterparts; similarities in the scaling behavior are revealed. For the lightweight isotopic defect in the linear chain, one encounters a typical dip of the temperature profile, related to weak excitation of the localized mode. If the nonlinear interactions are included, this dip can still appear at a relatively short timescale, with subsequent elimination due to the nonlinear interactions.

STUDY OF THE NON-ISOTHERMAL SEPARATION OF WATER DROPS IN THE EMULSION TAKING INTO ACCOUNT THE DEPENDENCE OF THE VISCOSITY OF THE OIL ON TEMPERATURE

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Non-isothermal stratification of an oil-water emulsion in a rectangular cell with height h is considered. The initial water phase concentration in the emulsion is C_0.

The problem is solved in a one-dimensional formulation in a diffusion one-temperature approximation. In the mathematical formulation of the problem, the following assumptions are made: an emulsion with the same droplet size, there is no convection of the emulsion system. The mathematical model includes a system of diffusion and thermal conductivity equations, written taking into account the forces acting on the emulsion droplets. Dependence of oil viscosity on temperature is taken into account [1].

The problem is solved in open-source software OpenFOAM using the finite-volume method. The standard OpenFOAM solver was modified for this problem.

Graphs of the temperature distribution of the water-oil emulsion and distribution of the water phase concentration at different times are built depending on the non-isothermal boundary conditions.

The reported study was funded by the grant of the Russian Science Foundation (project №19-11- 00298).

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A MODEL TO DESCRIBE THE BIOLOGICAL STIMULUS FOR BONE REMODELING WITH A DIFFUSIVE BEHAVIOR

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The mechanically driven biological stimulus in bone tissues regulates and controls the action of special cells called osteoblasts and osteoclasts. Some different models have been proposed to describe the important and not yet completely understood phenomena related to this feed-back process. Recently in Lekszycki and dell'Isola 2012 [1] an integro-differential system of equations has been studied to describe the remodelling process in reconstructed bones where the biological stimulus in a given instant *t* depends on the deformation state of the tissue at the same instant (see also [2]). Instead, biological knowledge suggests that the biological stimulus, once produced, is 'diffused' in bone tissue to reach the target cells. A model for describing biological stimulus diffusion in remodelling tissues in which 'diffusive' time dependent phenomena are taken into account is proposed. Some preliminary numerical simulations are presented which suggest that this model is promising and deserves further investigations.

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ON THINNING ICE: MODELING SEA ICE IN A WARMING CLIMATE

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Polar sea ice is a key component of Earth's climate system. As a material it is a composite which is structured on length scales ranging over ten orders of magnitude. A principal challenge in modeling sea ice is how to use information on small scale structure to find the effective or homogenized properties on larger scales relevant to coarse-grained climate models. In other words, how do you predict macroscopic behavior from microscopic laws? Similar questions arise in statistical mechanics, materials science, etc. I will give an overview of recent results on modeling effective behavior in the sea ice system. We consider fluid transport through the brine and polycrystalline microstructure, advection diffusion processes, ice floe dynamics, ocean wave propagation through the ice pack, and the evolution of ponds on melting Arctic sea ice. This work is helping to advance how sea ice is represented in climate models, and to improve projections of the fate of Earth's sea ice packs and the ecosystems they support.

TOPOLOGICAL EQUIVALENCE OF LOCAL QUALITATIVE SINGULARITIES OF DYNAMICAL SYSTEMS WITH IMPACT INTERACTIONS

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The report takes a general view of dynamic systems with impact interactions (vibro-impact systems). These are smooth differential equations of impact-free motions and a generalization of Newton's impact hypothesis.
For such systems, local qualitative singularities (six types) are determined [1]. A local singularity is a point on the impact the hypersurface S is zero. The order of the first nonzero derivative (due to the differential equations of motion of the system) determines the type of local singularity.
The study of these singularities is naturally limited to the notion of topological equivalence. Only the conditions that make it possible to prove such equivalence are the conditions that should be studied.
The first three types of identified local qualitative singularities are not difficult.
The fourth type of local qualitative singularities is a point on the surface S is zero in which the first derivative (due to the differential equations of motion of the system) is zero, and the second is negative. The movement of the system

occurs in the region S greater than zero. The fourth type for the proof of topological equivalence requires only the representation of infinite-impact motions by means of smooth differential equations [2]. Here, an infinite-impact motion is understood as a motion with an infinite number of impact interactions over a finite period of time.
The sixth type of local qualitative singularities is a point on the surface S is zero where the first and second derivatives (due to the differential equations of motion of the system) are zero, and the third is negative.
The sixth type (in addition to such differential equations [3]) requires a description of the behavior of the trajectories of the vibration impact system in this case. This description was carried out in [1].
The fifth type of local qualitative singularities is a point on the surface S is zero where the first and second derivatives (due to the differential equations of motion of the system) are zero, and the third is positive.
To prove the topological equivalence of the fifth distinguished type, we need:
a representation of infinite-impact motions using smooth differential equations [4];
a description of the behavior of the trajectories of the vibro-impact system, which was given in [1].

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MODELLING THE DYNAMICS OF A LARGE-SCALE INDUSTRIAL MANIPULATOR FOR PRECISION CONTROL

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FutureForge is a strategic programme in the University of Strathclyde Advanced Forming Research Centre (AFRC) which will deliver a 2,000 Tonne hydraulic press acting in three forging modes; open die, closed die and isothermal mode. The forging environment has been designed, and the principal aim now is to develop a mathematical model of the manipulator nonlinear dynamics, and to design a nonlinear control system to operate it in all the required modes, and then to build a virtual reality training simulator. The manipulator is used to carry metal ingots / bars from storage to the furnaces and then feed them to the hydraulic press for forging. The manipulator design is based upon three coupled parallelogram linkage sub-systems fitted with two independent hydraulic cylinders, configured to provide decoupled vertical and horizontal motions of the manipulator end-effector. The modelling is based upon classical Lagrangian mechanics and the mechanism is split into two separate operational phases which physically share the three parallelogram linkages, driving the end-effector vertically or horizontally, as required. Any combination of two-dimensional motion of the end-effector can be achieved, from any starting point to any end point location within the allowable configuration space. The two-dimensional kinematics of the system are described in terms of two generalised angular coordinates referred to an Earth-fixed frame of reference, with associated generalised forces that come physically from the hydraulic cylinders and the system geometry. Certain kinematic constraints imposed by the design are required to preserve the uniformity of the parallelogram linkage geometry during all aspects of operation, and some simplification of the kinematics is required for efficient computation in real time. The resulting model takes the form of two pairs of nonlinear ordinary differential equations, each pair governing vertical and horizontal phases of motion, respectively. The nonlinearities emanate physically from the configurational aspects of the machine. CAD simulations of the system kinematics suggest that there is no horizontal motion of the end-effector during a lift operation, although the full modelling shows that this is not strictly true and there are always small cross-couplings between the two phases of operation. The governing differential equations account fully for these small but important cross-coupling effects. The principal location of interest within the machine is the end-effector but to represent the machine properly all the motions of all the components of the machine must also be known. Considerable intermediate algebra arises from including all motions of every part of the machine and the derivation is strongly dependent on computer algebra. The result is a dynamic model capable of calculating the instantaneous position or velocity of any point within the machine, noting that this approach is contextually related to other studies of robotic systems, including those also containing flexible manipulators [1]. Current work is focused on model reduction without loss of accuracy, with a view to applying a suitable nonlinear control strategy to optimise the in-service performance of the system

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DISCRETE CONTACT PROBLEMS FOR DEFORMABLE BODIES

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Most technical surfaces are not perfectly smooth and deviate from the smooth shape at various scale levels. When they touch, the contact is localized on discrete spots (the real contact area). Discreteness of contact plays an important role in the course of physical processes occurring during contact and frictional interaction: elastic and plastic deformations, adhesion and cohesion, electrical resistance, mass transfer, wear and fatigue failure, surface tension and wetting, hydrodynamic phenomena in contact with a lubricant, etc.
The formulations of the periodic contact problems for wavy rigid bodies interacting with elastic and viscoelastic half-spaces are presented. The approximate approach to the determination of contact characteristics under conditions of a contact discreteness which is based on the localization method [1] is described. This approach makes it possible to take into account the mutual influence of the contact spots. Based on this method the dependencies of the actual contact area and pressure distribution on it on the surface shape and the value of the nominal (average for the period) pressure is determined and analyzed.
The solution of periodic contact problems makes it possible to calculate the additional displacement, which occurs due to the presence of a microrelief on the surface of the rigid body when it penetrates under a given value of the nominal pressure into an elastic or viscoelastic half-space, and to analyze the dependence of the additional displacement on the parameters of the microrelief (the shape of an individual asperity and the density of the asperities), as well as on the relaxation characteristics of the subsurface layers [2].
The proposed approach to modeling the contact interaction of elastic and viscoelastic bodies also makes it possible to evaluate the influence of the microgeometry of surfaces on the contact characteristics (the dependence of the load on approach, the distribution of nominal contact pressures) at the macrolevel, as well as on the distribution of internal stresses in thin subsurface layers of interacting bodies, which determine their fracture under conditions of frictional interaction.
The research is supported by the Russian Foundation for Basic Research (project 20-01-00400).
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MODELLING THE SKIN EFFECT IN METALS APPEARING DUE TO HYDROGEN ABSORPTION USING VARIOUS DIFFUSION MODELS

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Hydrogen embrittlement is one of the well-known problems in modern metallurgy. To a large extent, predicting the behaviour of a metal depends on the amount of hydrogen within the metal as well as its distribution. Experiments show that even low hydrogen concentrations strongly affect the strength of steels, and the maximum permissible hydrogen concentrations in modern alloys are about 50-100 times lower than in traditional ones. Recent experimental works have discovered the mechanism of hydrogen diffusion in steel from the external environment: it goes unevenly, forming a thin hydrogenated layer on the sample surface, beyond which there is practically no hydrogen in the material. The results of these works also show that this surface layer affects the properties of the material most.
This work presents various models of diffusion. All of the models consider the effect of mechanical stresses inside the metal on the hydrogen absorption from the external environment within the framework of the linear nonequilibrium thermodynamics approach. On the other hand, they consider various mechanisms of hydrogen accumulation, including the addition of a source term to the equation, as well as the classical Oriani trap model and others.
The problem of the hydrogen diffusion from the external environment into a cylindrical metal sample under external tensile stresses for each of the proposed models is solved. Furthermore, we assess the applicability of each of the models, study the influence of the model parameters on the hydrogen distribution for the considered boundary value problem and propose further improvements within the framework of each of the models.
The reported study was funded by RFBR, projects number 20-08-01100, 19-38-90298

A DISCRETE ELEMENT MODELLING OF WEAR PARTICLE FORMATION IN CONTACT BETWEEN SLIDING METALS

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The advanced discrete-element based mechanical model is presented. The model allows simulating contact interaction of ductile materials with taking into account fracture and surface adhesion by the cold welding mechanism. These competitive processes is described from a unified standpoint and uses plastic work of deformation as a criterion of both local fracture and chemical bonding of surfaces in contact spots.

The implementation of this model within the method of homogeneously deformable discrete elements (namely, movable cellular automaton method) made it possible not only to adequately model the formation and evolution of qualitatively different interfacial (third body) fragments but also to identify conditions favorable for the formation of specific types of interfacial fragments. The simulation results have shown that the type of interfacial fragments formed (wear particles or wedges) can qualitatively change when the mechanical confinement change in the direction normal to the sliding direction. In particular, we have shown that either equiaxial (rounded) particles weakly adhered to surfaces, or wedges/prows are predominantly formed depending on the degree of mechanical confinement of the contact region. Accordingly, the degree of mechanical confinement should largely determine the value of the friction coefficient, as well as the wear rate and the size distribution of wear particles.

The results of this study are relevant for a deeper understanding of the conditions for the implementation of various mechanisms of wear during sliding friction, as well as approaches to the control of these mechanisms.

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THEORETICAL STUDY OF THE INFLUENCE OF CUBIC SLIP SYSTEMS ON SINGLE CRYSTAL SUPERALLOYS INELASTIC DEFORMATION

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The plastic and creep deformation processes of single crystal superalloys are considered under complex variable thermomechanical loading. The aim of the investigation is to analyze theoretically the contribution of cubic slip systems in inelastic strains and thermal fatigue resistance.

The micromechanical models of the inelastic deformation of single crystal alloys were based on the assumption that the deformation process is the result of sliding in various slip systems [1]. There are two slip systems family for nickel-based superalloys: 12 octahedral slip systems {111}<011> type and 6 cubic slip systems {001}<011> type [2,3]. Energetically more favorable octahedral slip systems consist of four slip planes {111}, while in each of these planes there are three independent slip directions <011> [2,3]. The cubic slip system is characterized by three {001} planes with two independent directions <011> in each of these planes [4]. Twinning and diffusion are not considered in this investigation.

The approach for the parameters identification of scleronomic and rheonomic micromechanical models of inelastic deformation of the face-centered cubic single crystal with taking into account the presence of octahedral and cubic slip systems was developed. Contribution of cubic slip systems in plastic strain and hysteresis loop width for AM1 nickel-based superalloys cylindrical specimen loaded in tension-compression with different crystallographic orientations ([001], [011], [111], and [123]) was appreciated.

The developed model accounting both octahedral and cubic slip systems is used for finite element computations of cooled single-crystal blades of modern gas turbines under complex non-proportional combined thermomechanical action.

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INFLUENCE OF HEAT TRANSFER AND GEOMETRY ON MICRO-THRUSTER PERFORMANCE

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Changes in the geometry and thermal conditions of the walls of micro-thrusters used in microspacecraft affect the development of their internal boundary layer and the thrust performance of the micronozzles.In this paper, the numerical simulation of the internal flow of the micronozzles structure under the condition of rarefied gas is carried out. Based on the DSMC method, from the perspective of molecular dynamics, a numerical model of the influence of gas flow in the micronozzles on its performance was established. The present work analyzes viscosity and rarefied gas effects caused by large surface-area-to-volume ration plus low Reynolds number of the micro-nozzle, and non-equilibrium effects in the micro-nozzle flow field. The influence law of different shapes designs, such as bell-shaped, flared and conical, on the flow field of micro-nozzle and its thrust performance is studied. The coupling model of gas flow and wall heat transfer inside the micronozzle is used to analyze the influence of wall heat transfer on the overall performance of the micronozzle.The results show that the viscous
shear effect along the nozzle wall in the subsonic boundary layer of the nozzle expansion section hinders the overall flow and reduces the perform-ance of the nozzle. Under micro-scale conditions, the wall thermal conductivity has a large influence on the flow field performance parameters of the nozzle expansion section.

THE DILATATION LINE IN A WEDGE-SHAPED ELASTIC BODY WITH FREE SURFACES

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Investigation of the misfit strains and stresses attributed to semiconductor nanoheterostructures of complex architecture is a significant problem of materials science and nanomechanics. These strains and stresses are mainly determined by the differences in lattice parameters and thermal expansion coefficients of materials in contact as well as their chemical inhomogeneities. They are also affected by real faceting shape of heterostructures. The relaxation of misfit stresses through the formation of various defects is often accompanied by deterioration of functional properties of the heterostructures and their subsequent failure. Therefore, thorough analysis of misfit stresses in heterostructures with account for their real faceting shape is of great importance for creation of defect-free semiconductor devices with enhanced performance. With this aim, we have found an analytical solution of the boundary-value problem in the classical theory of elasticity for a wedge-shaped body containing a straight line subjected to 3D dilatation eigenstrain that is the so-called ‘dilatation line’. Similar problems for edge dislocations in homogeneous[1] and composite[2] wedge-shaped bodies and screw dislocations placed near a triple junction of different wedge-shaped phases[3] were solved long ago by the method of virtual surface dislocations.
Consider a dilatational line placed in wedge-shaped elastic body with stress-free surfaces. To determine the stress field of this defect, we introduce the Airy stress function in the form of a sum $\psi = \psi_{el} + \psi_{pl}$, where ψ_{el} is an analytical solution of the biharmonic equation in the elastic problem for the wedge and ψ_{pl} is the particular solution which corresponds to the dilatational line. The Mellin integral transform is employed to derive a set of equations for the Airy stress function. As a result, the desired stress components are found in an integral form, as the inverse Laplace-Mellin transforms. The analysis of the obtained solution was done numerically by using the stress plots.
The found solution satisfies the equilibrium equations and the boundary conditions on the free surfaces of the wedged body. The free surfaces strongly affect upon the stress field distribution.
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MICROMECHANICS OF MISFIT STRESS RELAXATION IN CORE-SHELL NANOWIRES WITH LONG PRISMATIC CORES OF SQUARE CROSS SECTION

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The development, fabrication, characterization and application of various solid-state nanoscaled heterostructures are one of the main topics in the technology of materials for laser photonics and optoelectronics. The combination of materials with different crystal lattice parameters and thermal expansion coefficients in such heterostructures leads to the appearance of high elastic misfit strains and stresses in them [1, 2]. Under certain conditions, these strains and stresses begin to relax due to the nucleation and development of various defect structures [1–3] which are, in most cases, misfit dislocations (MDs). Studying the mechanisms of MD formation and determining the critical conditions for their onset are extremely important both for understanding the physical processes of structure development in inhomogeneous nanoscale solids and for improving the technology of their production.

In this work, some theoretical models of the mechanisms of the formation of straight MDs in cylindrical core-shell nanowires with a core in the form of a long straight square prism, located symmetrically relative to the cylindrical surface of the shell, are suggested and analyzed in detail. We have calculated the changes in the energy of such a system during the formation of MDs and found the energy barriers for the nucleation of individual perfect and partial dislocations by sliding and climbing from the free surface of the shell, as well as by the emission of dipoles of such dislocations by the edges of the prismatic core. It is shown that, depending on the diameter of the nanowire and on the transverse size of its core, the energetic preference for the activation of one or another relaxation mechanism changes. For example, in a nanowire consisting of an Au core and a Pd shell, the most preferred mechanism is the emission of dislocation dipoles by the edges of the core. In this case, in thinner nanowires, the emission of partial dislocations is more favorable, and in thicker nanowires, it is more favorable for perfect dislocations. The results obtained are compared with available experimental data.

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NUMERICAL SIMULATION OF THE TANK FILLING WITH A VISCOUS FLUID UNDER PRESSURE BY THE VOF METHOD

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A Newtonian fluid flow with a free surface occurring at the initial stage of the filling of a plane vertical tank with a central body in the gravity field is numerically simulated. The flow region represents a channel with a sudden expansion at the inlet section of the tank with a central body, which is located at a given distance from the expansion plane. The fluid is supplied under pressure from the tank bottom through a channel of a smaller width. At the initial time instant, the narrow channel is filled with the fluid, and the free surface has a flat shape. A system of governing equations includes the Navier-Stokes and the continuity equations. Mathematical formulation of the problem, written in terms of dimensionless variables, involves the following parameters: the Reynolds number, the Froude number, and the geometric characteristics of the flow region. A velocity profile, corresponding to a steady viscous fluid flow in a plane infinite channel, is specified as a boundary condition in the inlet section of the narrow channel. No-slip conditions are used on the solid walls. In accordance with the VOF method, the continuity conditions for normal and tangential stresses are satisfied on the free surface.

The problem is numerically solved by the finite volume method using the SIMPLE algorithm. The free surface evolution is determined with the use of a computational technology of the VOF / PLIC method.

As a result of parametric calculations, various regimes of the flow formation are revealed in the expansion plane vicinity, depending on the governing parameters:

1. The fluid completely overlaps a gap between the inlet of the wide channel and the central body, and then spreads over the tank bottom. This regime is provided when gravitational forces dominate over viscous and inertial forces.
2. The fluid jet strikes the central body and then falls down to the tank bottom. This regime is observed when viscous forces dominate over inertial and gravitational forces.

3. The fluid flows over the central body and does not fall down to the bottom. This regime takes place when there is a strong domination of viscous forces over inertial and gravitational forces.
The research is implemented at the expenses of the Russian Science Foundation (project No. 18-19-00021-П).

SPREADING OR CONTRACTION OF VISCOUS DROPS BETWEEN PLATES: SINGLE, MULTIPLE OR ANNULAR DROPS; WITH A HINT OF ROTATION

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The behaviour of a viscous drop squeezed between two horizontal planes (a contracting Hele Shaw cell) will be described by both theory and and experiment. For a constant squeezing force the ultimate growth of the radius a ~ t^(1/8) with time t. An initially elliptic drop tends to become circular as t increases and is stable to small perturbations. For a reversed force, so that the plates are drawn apart, the boundary of the drop is subject to a fingering instability on a scale determined by surface tension. The eff ect of a trapped air bubble at the centre of the drop will also be described. The annular evolution of the drop under constant squeezing is still found to follow a 'one-eighth' power law, but this is unstable, the instability originating at the boundary of the air bubble. If the plates are drawn apart, the evolution is still subject to the fingering instability driven from the outer boundary of the annulus. Fingering can also spread from the boundary of an interior trapped air bubble, and small cavitation bubbles appear in the very low pressure region far from the point of leverage. The effect of rapid rotation of the plates about a vertical axis will be described: unstable to fingering at the interface if no upper plate present; and totally stable if there is an upper plate. All these behaviors will be described, as well as being demonstrated by real time experiments and videos.

HOLOGRAPHIC AND INTERFERENCE METHODS FOR REGISTERING THE SURFACE SHAPE IN GASDYNAMIC EXPERIMENTS

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The results of experimental researches of surface shape registration methods are presented: based on Michelson interferometer, shear interferometer, and structured light. Algorithms and results of experiments with static and dynamic objects are described.
One of the tasks in the research of gas-dynamic processes is the registration of surface relief deformations under shock-wave loading. Used various holographic and laser-interferometric methods helps solve this problem. Schemes based on a Michelson interferometer can be used to register small displacements (approximately ten of microns). In this case, the signal wave scattered by the test sample interferes with the reference wave reflected from the mirror. The methods based on the shear interferometer are practically not limited by the magnitude of the displacement, however, they are sensitive to sharp relief gradients. The structured light method is based on the interference of two converging beams on the sample surface, and most suitable for recording macro displacements (more than 50 μm), but has a low sensitivity for micron displacements.
In the report analyzes various limitations for the above-mentioned methods, presents the results of experimental and computational researches for the registration of the surface relief of the samples in static and dynamic conditions.

NUMERICAL RESEARCH OF SUSPENSION FLOW IN RECTANGULAR CHANNEL WITH PERMEABLE WALLS

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Simulation of suspension flow in channels of different type occurs in hydraulic fracturing. The hydraulic fracturing technology consists of creating a high conductivity fracture in the formation to ensure the flow of the produced fluid. The suspension consists of water-based solutions (carrier fluid) and proppant. One of the problems of proppant transportation in the fracture is associated with fluid leakage from the fracture into the formation. While applying numerical simulations for concentrated suspension flow modeling, it is important to take into account such effects as interactions between particles, flow regimes, and gravitational forces. To study the laminar flow of a suspension in a flat channel, a one-fluid approach was chosen, in which the carrier liquid and the solid particles suspended in it are considered as one [1].

The mathematical model includes the equation of continuity for suspension, equation of motion of the suspension, the balance equation in the form of a convective-diffusion equation for the transfer of the volume concentration of particles. To validate the mathematical model and test the solution algorithm, the simulation results were compared with the experimental data given in [2].
The solution of the system of equations of the mathematical model was carried out by the control volume method in the OpenFOAM software package. A study of the flow of a viscous incompressible fluid with suspended solid spherical particles in a rectangular channel in the presence of leakage was carried out. The results obtained can be used to carry out estimated calculations of the advance of the particle front, depending on the parameters of the suspension.
The reported study was funded by RFBR, project number 19-31-90157.
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THE T-SCHEMES FOR THE BOUNDARY INTEGRAL EQUATION SOLVING IN VORTEX METHODS OF TWO-DIMENSIONAL FLOW SIMULATION AROUND AIRFOILS

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The problems of two-dimensional flow simulation around airfoils arise in number of engineering applications connected with structures interaction with a flow. Wide range of numerical methods are known for such problems; in the present research vortex methods are considered. Modern mathematical models make it possible to consider viscous incompressible flows remaining in the framework of purely Lagrangian numerical methods. Vorticity is considered as a primary computational variable in vortex methods, while velocity field as well as pressure distribution can be reconstructed according to the Biot-Savart law and the Cauchy-Lagrange integral generalization. Note, that integral hydrodynamic loads that act on the airfoil, can be easily computed without pressure reconstruction.
One of the most unobvious problem in vortex methods implementation is connected with the no-slip boundary condition satisfaction. It is provided with vorticity generation on the walls. An implicit numerical scheme is used, and thin vortex sheet on the airfoil surface line is introduced, which intensity is solution of a vectorial boundary integral equation (BIE). Two approaches of its numerical solution are known; the first one consists in projection of the BIE onto normal unit vector, that corresponds to the no-through condition implementation. It leads to the solution of singular BIE of the 1-st kind, where the integral is understood in Cauchy sense. The numerical schemes for such equations do not provide high accuracy even for uniform boundary discretization.
The other approach is connected with the BIE projection onto tangent unit vector, expressing the no-slip condition. It leads to the 2-nd kind BIE with bounded (for smooth airfoils) or absolutely integrable (for airfoils with corner points) kernel of Fredholm-type. The numerical schemes for its numerical solution, that are based on the Galerkin and Petrov-Galerkin methods, allow for the significant improvement of the accuracy, even for rather coarse surface meshes.
In the present research the hierarchy of numerical schemes is discussed, that can be applied for the numerical solution of the BIE, arising in vortex methods for incompressible flow simulation around the airfoils of arbitrary shape. The schemes are considered that provide the 1-st and 2-nd orders of accuracy for smooth airfoils. New schemes are suggested, that make it possible to exclude the weak singularity of the numerical solution at corner points of the non-smooth airfoils. Number of test problems are considered for the airfoils with known exact solution (elliptic airfoils, Zhukovsky wing airfoil with cuspidal point, its generalization with corner point), that confirm the accuracy of the developed schemes. The problem of the added mass tensor computation is also considered, and it is shown that the developed numerical scheme provides the 2-nd order of accuracy.

ANALYSIS OF EFFECTIVENESS OF PILE BARRIERS FROM RAYLEIGH SURFACE WAVES WHEN PILE FIELD GEOMETRY CHANGES

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Analysis of damage to structures during earthquakes shows that the greatest damage occurs in the foundation structures of buildings as a result of the impact of surface waves of Rayleigh, Love, and Rayleigh-Lamb. They can also be anthropogenic. From the penetration of these waves to the territories of buildings, there are methods based on the creation of various types of barriers that dissipate the energies of surface waves, since design methods of seismic protection aimed at creating earthquake-resistant structures in these cases turn out to be ineffective. Pile barriers located outside protected buildings and structures protect the foundation slab, which as a rule remains unprotected when applying other seismic protection methods. The present paper presents finite element models of pile barriers of acoustic medium in the form of a pile field surrounding the protected area. Comparative studies were carried out for the effectiveness of pile barriers from different diameters. The obtained data from the results of the present studies showed that as the diameter of the pile barriers increases, the corresponding displacement magnitudes in the protected area decrease.

FATIGUE OF AUSTENITIC STEEL: MICROMECHANICS ASPECTS

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Microstructural changes under low-cycle fatigue of a metastable austenitic steel are monitored by a combination of the acoustic parameters: Poisson’s ratio change as indicator of the “diffused” damage and anisotropy change as indicator of changes of texture. Three stages of the Poisson’s ratio evolution are identified; they serve as markers of the process of material degradation. A criterion of fracture in terms of a critical combination of the changes of the mentioned parameters is proposed and tested. The challenge of separating the effects of damage accumulation and of the martensitic transformation on Poisson’s ratio is addressed by combining acoustic monitoring with the eddy current data. It is also found that the microcrack density at the fracture point is proportional to relative volume of the strain-induced martensite.
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ELECTRON DYNAMICS OF TIP-TUNABLE OXYGEN SPECIES ON TIO2 SURFACE

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We study oxygen atoms adsorbed on TiO_2 surface in the form of reactive oxygen species and single-atom quantum dots, that can exist in two redox states with the charge of minus one or two. The redox state of the oxygen species can be switched by atomic force microscopy (AFM) tip by means of electron tunnelling between the tip and dot, so measuring transition rates is essential. We acquired tunnelling rates at 78 K over a wide range of tip-sample distances and applied voltages. In spite of the usual culprit of thermal drift that forced previous measurements to be only conducted at ultra-low temperatures to collect enough statistics, we realised a fast highly sensitive probing tool/device which directly benefits from the stochastic nature of the tunnelling. This enabled us to study multiple dots and provided unexpected insights into the electronic structure and correlation between the oxygen species which remain hidden in the ordinary AFM microscopy. We also show that single-atom quantum dots in the two charge states have drastically different conductance, one being conducting the other non-conducting, which enables one to fabricate a desired binary surface arrangement of such dots (e.g., “anti-” and “ferromagnetic”) that may be considered as a simplest quantum nanodevice.

ON THE LS-STAG IMMERSED BOUNDARY CUT-CELL METHOD USAGE FOR NUMERICAL INCOMPRESSIBLE FLOW SIMULATION AROUND AIRFOILS SYSTEM

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The problem of two-dimensional viscous incompressible flow simulation around rigid airfoils of arbitrary shape is considered. The LS-STAG immersed boundary method is used for its numerical solving. This method is based on the accurate discretization of the governing equations in cells that are cut by the boundary and provides the second order of accuracy.
A number of problems of incompressible flow simulation around fixed airfoils are considered. In particular, an

incompressible flow around a fixed circular airfoil is simulated at various Reynolds numbers. It is shown that the LS-STAG method allows one to obtain values of dimensionless aerodynamic drag coefficient and lift coefficient that agree well with the data known in the literature. The problem of determining of separation point for flow around a circular cylinder is also considered. It is shown that when solving this problem by using the LS-STAG method on rather coarse grids, the results are in good agreement with the results of studying this problem by other methods.
A coupled two-dimensional problem about simulation of low-speed subsonic flow around circular airfoils system with two degrees of freedom is considered. The LS-STAG immersed boundary method modification (it is developed and implemented in the form of a software package) was used to perform the computations. This modification allows simulating the flow around moving airfoils on a fixed sufficiently rough rectangular structured grid. The obtained results are in good agreement with the data known in the literature. The developed numerical method can be efficient for numerical solution of a wide class of coupled aerohydrodelastic problems.

STRESS FIELD FOR A CYLINDRICAL SHELL WITH A CIRCULAR HOLE UNDER DIFFERENT BOUNDARY CONDITIONS

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In this work cylindrical shell with a circular hole under different boundary conditions is considered: tension applied at infinity along generating axis, loading by internal pressure and torsion.
The interest in this problem has been observed for a long time since A. Lurie in the 1940s formulated the governing equation and proposed an analytical approach containing an expansion in a small parameter. The tedious process of solving this problem led to cumbersome results that were applied for a very small range of applicability. He was followed by a whole plead of scientists who tried to improve his ideas but faced similar problems. Since the 1960s many researchers have approached the task using numerical methods such as the collocation method but these results differed from each other makes it hard to rely on it. With the advent of FEM, attempts at an analytical solution were buried. However, until now, the relevance and applicability of this problem remain high, especially in the field of the aviation industry.
The authors of this work present a new analytical approach without an expansion in a small parameter that has strong mathematical justification and has no mathematical restrictions. All restrictions have only a mechanical sense. During the presentation, the history of the question, analysis of previous works, comparing results are observed.
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EFFECT OF BONE DENSITY ON THE STRESS STATE NEAR SCREW RETAINED DENTAL IMPLANTS

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The effectiveness of dental implantation depends, among other factors, on bone density, which can vary over a wide range. A change in bone tissue density leads to changing in its elasticity modulus. This fact makes it possible to perform mathematical modeling of bone density effect on the stress-strain state with quasi-static load application by changing the elastic modulus of the bone.
A computational study the stress-strain state of bone tissue dependence on its density was performed by using the methods of finite and boundary elements. The calculation of the implant and the surrounding bone tissues stress-strain state was carried out for plane strain state and consisted of two stages: 1) calculation of the entire implant structure with smoothed screw join between implant and the surrounding bone tissue; 2) study of the of stresses distribution in the screw connection in the zone of adhesion of the implant to the bone tissue. The calculations were performed under the assumption that the bone tissue is an isotropic and homogeneous elastic material.
It was found that the dependences of the maximum equivalent stresses in the cancellous and cortical bone tissues on the elastic moduli of bone tissues are similar for all the considered calculation models. With an increase in elasticity modulus of cancellous bone tissue (increasing in bone stiffness), part of the load transferred to this bone tissue is increased. In view of this, the maximum equivalent stress in the cancellous bone also is increased. With increasing in the elastic modulus of the cancellous bone stresses in the cortical bone is decreased due to a decrease in the load transmitted to this part of the bone. The stresses in the cancellous bone decrease with an increase in the elastic modulus of the cortical bone. The level of the maximum equivalent stresses in the cortical bone is increased with an increase in the elastic modulus of this bone tissue. The maximum equivalent stresses in the bone tissue are observed in the cortical bone near the neck of the implant. The calculated maximum equivalent stresses in the cancellous and cortical bone

tissues when changing the elasticity moduli of bone tissues do not exceed the corresponding strength limits.
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USING ARTIFICIAL NEURAL NETWORKS TO PREDICT IMPACT STRENGTH OF TARGETS WITH PERFORATION

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The work considers application of artificial neural networks (ANN) for fast numerical evaluation of a residual impactor velocity for a family of perforated PMMA targets. The ANN models were built using data obtained via dynamic finite element analysis of the plates' failure using specialized dynamic fracture model. The constructed approach makes it possible to evaluate the impact strength of a particular target configuration without complicated FEM calculations which require considerable computational resources. Moreover, the ANN models are able to predict results for the configurations which cannot be calculated using FEM due to numerical instabilities. Additionally, scaling of the ANN models is briefly covered and some insight into the perforation pattern optimization using the trained ANN is also made.

BALLOON DILATION ANGIOPLASTY OF AORTIC COARCTATIONS IN ONE-YEAR-OLD CHILDREN

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In this work, we performed numerical simulation of blood flow development in the aorta with coarctation and in the healthy aorta using the finite element method, as well as simulation of coarctation segment wall expansion by balloon dilatation. The work can be divided into several parts: construction of a parameterized model according to anatomical atlases and data of morphological studies; construction of a finite-element model according to the obtained geometry; numerical hydrodynamic experiments on the diseased aorta, as well as on a healthy one; simulation of the process of wall dilation by balloon exposure with a given pressure on its inner surface; stress and displacement analysis on aortic walls; and analysis of blood fluid dynamics.
In the presence of elastic properties and individual geometry of the aortic walls, we can solve the problem of hydrodynamics and elasticity theory in a nonlinear formulation. Based on our study, we can make recommendations to avoid negative, as well as fatal, outcomes during surgery. The simulation allows us to determine how much pressure should be applied to the balloon for the coarctation segment to increase by 30% in diameter.

STABILITY OF SHOCK WAVES IN A TWO-PHASE VAPOR-LIQUID MIXTURE OF A METAL

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The report proposes a real mechanism of rotation of planets, stars, black holes around their axis, under the action of the longitudinal component of the magnetic field. The question of what forces rotate around its axis planets, stars, black holes and the quasars born by them has no answer in modern physics. If we extend the experiment in the Nikolaev's paradoxical electromotorto a global scale and if as an engine we consider the planet earth, on a surface of which a negative electric charge $Q = 5{,}16 \cdot 10^{14}$ coulomb is concentrated, while along an outer sphere such currents go, which generate a magnetic field of 50 a/m then it will Axial rotation of the Earth would depend on the same longitudinal magnetic field forces, as in the Nikolaev's paradoxical electromotor [1]
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GENERATION OF LONGITUDINAL UNDULAR BORES IN PMMA BARS FOLLOWING TENSILE FRACTURE

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The generation of undular bores in polymethylmethacrylate (PMMA) bars following tensile fracture is registered using high-speed pointwise photoelasticity [1]. We show that a viscoelastic extended Korteweg - de Vries (veKdV) equation provides a very good agreement with the key observed experimental features of the generated bores for a suitable choice of material parameters. Linearisation of the veKdV equation near the pre-strain level prior to fracture captures some features at the front of the bore. We analyse the behaviour of the bores following both natural and induced tensile fracture. We also vary the cross section of the waveguide and conditions at fracture. Such waves could be present in the signals generated by fracking, earthquakes and other events involving transverse fracture of an appropriately pre-strained waveguide.

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REVISITING A. V. POPOV'S DIFFRACTION PROBLEM

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We aim at a construction of high-frequency asymptotic formulas for a wavefield described by the scalar 2D Helmholtz equation. The wavefield satisfies the Neumann condition on the boundary C which is made up of the half-line $C_{-} = \{y = 0, x < 0\}$ and a piece of smooth contour C_{+}. Important is that C has a jump in curvature at the conjugation point O. The incident wavefield is a plane wave $\exp(ikx)$, where $k >> 1$ is the wavenumber. The problem has been earlier addressed in [1] by Alexey Vladimirovich Popov (now in Troitsk, Moscow) who ingeniously used a combination of parabolic-equation approach, Kirchhoff-type heuristics and Malyuzhinets technique to derive an expression for the cylindrical wave arising at the non-smoothness point O.

We describe the outgoing wavefield u^{out} in a neighborhood of O through a formal employment of the Leontovich—Fock parabolic-equation method [2, 3]. With this we continue our earlier work on the systematic application of boundary-layer techniques to diffraction by a jump of curvature and similar diffraction problems [4, 5]. We introduce the standard stretched coordinates [2, 3]

$$S = k^{1/3}\, s, \qquad N = k^{2/3}\, n,$$

where s is the arc length of the contour C measured from the singular point O and n is the length of normal to C. We seek the outgoing field in the form of the Leontovich—Fock Anzatz:

$$u^{\text{out}} = \exp(iks)W(S, N).$$

Substitution this Anzatz into the Helmholtz equation gives, to the main order, the parabolic equation

$$W_{NN} + 2\mathrm{i}W_S + 2\varkappa H(S)NW = 0 \tag{1}$$

with the boundary condition

$$W_N\,|_{N=0} = -\mathrm{i}\varkappa H(S)S\,\exp(-\mathrm{i}S^3/6) \tag{2}$$

Here, $H(S) = \{1, S > 0;\ 0, S \leq 0\}$ is the Heaviside step function, $\varkappa$ is the value of curvature of C_{+} at the point O.

We explicitly solve the problem (1)–(2). The solution is somewhat similar to that presented in [2, 3] for a smooth contour, but with some classical Airy functions replaced by inhomogeneous Airy functions. We derive formulas for the wavefield in the vicinity of the limit ray. Similarly to [2, 3], the wavefield is a sum of the classical Fresnel field and a background field which is described by a novel special function. The expression for the diffracted wave which we obtained agrees with the one found in [1].

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INFLUENCE OF THE STRESS-STRAIN STATE ON THE COMPOSITION OF SYNTHESIS PRODUCTS IN THE GAP BETWEEN TWO INERT MATERIALS

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Synthesis of intermetallic or composite coatings and layered composites has been popular in recent years. There are also a number of works of a theoretical nature that attempt to describe the process of structure formation. However, the related nature of processes of different physical nature is rarely taken into account. Without taking these factors into account, it is impossible to predict the composition and properties of new materials. The present work analyzes a coupled model of synthesis of a composite with strengthening inclusions in the gap between two inert materials. The process is initiated and maintained by a moving heat source coupled to a moving heated roll. Two total reactions are considered, the first of which leads to the formation of hardening particles; the second leads to the formation of a matrix of complex composition. The aim of the work is to investigate the role of cross-effects arising when considering the mutual influence of temperature, concentration, stress and strain fields. The peculiarities of the stress-strain state under these conditions are studied, as well as its role in controlling the synthesis process.
This work was supported by the Russian Foundation for Basic Research, grant № 20-03-00303

COUPLED THREE-FREQUENCY ENVELOPE SOLITONS IN THE PROPAGATION OF LONGITUDINAL WAVES IN A NONLINEAR ACOUSTIC METAMATERIAL

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Acoustic (or mechanical) metamaterials, being, in fact, not materials, but cellular periodic structures, in the long wavelength range behave like continuous materials. The study of the features of dispersion, dissipation and manifestation of nonlinearity of acoustic waves in metamaterials is of interest. This interest is due to both the cognitive aspect of the issue and the prospects for practical applications of metamaterials, among which the possibility of creating super absorbers of sound on their basis is increasingly called.
Guided by the mathematical analogy between acoustic and electromagnetic waves, many researchers have tried to construct continuous models of mechanical metamaterials. However, it was not possible to achieve great success on this path, since mechanical analogs of real-life materials with negative dielectric constant are deformable solids with negative mass, density, or negative modulus of elasticity. And such materials do not exist in nature.
It was possible to avoid this disadvantage on the way of structural modeling of metamaterials.
The paper proposes a mathematical model representing a chain of oscillators, consisting of nonlinear elastic elements and masses, each of which contains an internal nonlinear oscillator. This model describes a class of mass-in-mass acoustic metamaterials. The resulting system of equations in the long-wave approximation can be reduced to the nonlinear evolutionary Benjamin-Bona-Mahony equation, which shows that in the metamaterial-paradynamic action, spatially localized non-linear strain waves (solitons) can form.
In addition, within the framework of the Benjamin-Bona-Mahony equation, the interaction of three modulated quasi-harmonic waves (wave packets) is investigated under the conditions of phase matching. The formation of coupled three-frequency envelope solitons is also investigated, i.e. wave packets that retain their amplitude-phase profiles during propagation in a metamaterial due to the compensating action of nonlinear effects.
This work was supported by the Russian Science Foundation (grant No. 19-19-00065).

BIONIC CIVIL AIRCRAFT STRUCTURES BASED ON LATTICE COMPOSITE GRIDS AND PROTECTIVE COATINGS

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Bionic structures of civil aircrafts is a brand new direction of research, which actuality is caused by low weight effectiveness and a number of critical strength problems of up-to-date composite aircraft structures, based on

conventional semi-monocoque layouts. The main idea of bionic aircraft structure concept is building a structure in the same way as it is realized in the human organism: stiff skeleton acts as a load-bearing structure, muscles support and protect the skeleton and skin serves as a protection of this “structure” from the environment.
Bionic concept turned out to be very suitable for current composite materials, based on high-strength carbon fiber and epoxy resin. For composites, having high strength along fiber orientation, building “skeletons” based on unidirectional composite ribs is a very perspective way to get best weight effectiveness, as such skeletons can be reliably protected against impacts and climatic factors, being critical for composite materials.
Composite aircraft structure based on bionic layout has the following main parts: stiff lattice grid, protective coating for the grid, internal pressurized skin, external smooth skin. Functions of the structure are distributed among these elements: grid serves as the main load-bearing element, pressurized skin keeps the internal pressure inside the cabin, outer skin forms the aerodynamic shape and protective elements provide impact and climate protection for the grid. The bionic approach of distribution of structure function among elements is opposite to the one in conventional structures, where stiffened skin bears almost all these functions by itself.
This work gives an overview of the activities aiming to build weight effective bionic structure of fuselage barrel for perspective civil aircrafts, including numerical and experimental researches.

ENERGY-OPTIMAL CONTROL BY BOUNDARY FORCES FOR LONGITUDINAL VIBRATIONS OF AN ELASTIC ROD

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This work is devoted to controllability and optimization of vibrations of mechanical systems with distributed parameters. The longitudinal displacements of a thin rectilinear elastic rod are studied. Based on the method of integro-differential relations developed by the authors, a generalized statement of the initial-boundary value problem is proposed, which solution is sought in terms of kinematic and dynamic variables defined in a Sobolev space. The critical time such that the system can be brought to a terminal state is determined for the case of a homogeneous rod controlled by external forces applied at its ends. For fixed time intervals longer than the critical one, the control problem of optimal transfer of the system to the zero state is considered. In this case, the minimized functional has the form of the weighted sum of the mean mechanical energy stored by the rod during its motion and the integral quadratic norm of control functions. By using D’Alembert’s representation, the solution to the direct dynamic problem is derived in the form of traveling waves. By taking into account the properties of the generalized solution, the control problem, which is two-dimensional in space and time, is reduced to a classical one-dimensional quadratic variational problem. The latter has a set of traveling waves as unknowns. As a result, the optimal control law and the corresponding motion of the rod are obtained explicitly. Finally, energy characteristics of the optimal motion are analyzed depending on the control time and the weight coefficient in the cost functional.

RETINAL PULSE WAVE VELOCITY: NON-INVASIVE ASSESSMENT OF ARTERIAL STIFFNESS IN THE CENTRAL MICROCIRCULATION

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Blood vessels become stiffer because of the combined effects of aging, high blood pressure, and other factors. These alterations occur primarily in small vessels in different organs and systems of the human body. However, despite their high potential prognostic relevance, methods to investigate vascular stiffness in the microcirculation are scarce and require at present invasive generation of vascular material.
A novel clinical approach is proposed which characterizes in-vivo arterial stiffness in the central microcirculation. Pulse wave propagation in retinal arteries is assessed and a surrogate parameter “retinal pulse-wave velocity" (rPWV) is determined non-invasively using principles of dynamic retinal imaging and methods of mathematical signal analysis. Time dependent alterations of vessel diameter are measured with the Retinal Vessel Analyzer (IMEDOS Systems, Jena, Germany) at different locations within a chosen segment of a retinal artery. Data samples are filtered at the 10th harmonic (multiple) of the heart rate and temporal shifts are determined using cross-correlation function.
Reliability and short-time reproducibility of rPWV-assessment have been tested in pilot clinical studies. The new clinical method of rPWV-assessment in retinal vessels shows stable reference values and slight age dependence of retinal arterial stiffness in validated healthy volunteers. Retinal arterial stiffness characterized with rPWV is elevated in aged volunteers with not excluded cardiovascular risk as well as in patients with arterial hypertension. Moreover, rPWV shows microvascular alterations already in pre-clinical stages of arterial hypertension giving insight into early

diagnostics of cardiovascular disorders.

SELF-SUSTAINED VIBRATIONS OF THE PENDULUM UNDER BI-HARMONIC FORCING

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In our work, we investigate self-sustained oscillations in a system of a weakly damped pendulum under the action of two harmonic forces with close frequencies. Without limitations on the amplitude of oscillations, we construct asymptotic procedure with use of a semi-inverse method to obtains a system of reduced-order equations. Separating the dynamics of the system into fast, slow, and super-slow time-scales, we show that the movements of the pendulum on the fast and slow scales turn out to be decoupled. The system of equations for the amplitude of the envelope and the phase of the state function in the leading approximation on a slow scale becomes autonomous when the super-slow time parameter depends rather weakly on slow time and can be considered a constant, which later is considered as varying adiabatically slow. Stationary solutions in a slow-time system are investigated as functions of super-slow time. Using this technique, one can analytically study relaxation oscillations in a wide frequency range, as well as their dependence on the friction coefficient. The results obtained are in good agreement with the numerical solution of the original system.

PERMEABILITY EVOLUTION DURING FLOODING

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Dynamic loads can affect the manifestation of various properties of rocks, including permeability [1-3]. During the development of hydrocarbon fields, the appearance of dynamic loads is mainly due to a change in pore pressure. The pore pressure can change while water is injected for maintaining the reservoir pressure. As studies of the results of field well testing have shown, with a decrease and increase in pore pressure, permeability hysteresis is observed, although water injection contributes to an increase in reservoir pressure, however, it does not allow restoring the initial productivity of producing wells [4,5]. The lack of information on a possible decrease in permeability during production leads to the adoption of erroneous options for field development. For example, a decision is made to start late water injection to maintain reservoir pressure. For a detailed account of the permeability evolution with a change in pore pressure, it is proposed to use the Two-Part Hooke's Model (TPHM). Modeling of permeability evolution in work [6] showed the adequacy of the proposed approach. In TPHM, a soft spring can be described by an exponential or power equation, and a hard spring can be described by a linear one. Determination of the coefficients of the equations can be carried out based on the results of field well tests, but this can be difficult due to the lack of statistical information on the development of a new field. This paper proposes a method for determining the coefficients of the equations describing the permeability evolution with varying pore pressure, based on the results of core studies.

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THE PHENOMENON OF RESIDUAL STRESS RELAXATION IN DECAHEDRAL PARTICLES VIA VOID FORMATION

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The small crystalline metal particles taking shape pentagonal prism, icosahedron or decahedron have been distinctly investigated for the last four decades [1]. The five-fold symmetry of these particles arouses the inhomogeneous residual stress state storing the strain energy proportional to the particle volume. This strain energy could relax through the various channels including the generation of dislocations, low-angle grain boundaries and microtwins and the formation of voids, open gaps, lattice mismatch layers, inclusions and surface whiskers [2]. This research is aimed to elucidate the stress relaxation phenomenon in decahedral particles (DhPs) due to the formation of spherical central void [3].
The quasi-equilibrium energetic approach was employed to develop the theoretical model of the aforementioned phenomenon. According to this approach, the balance of surface and strain energies in DhP during the void growth was considered to obtain the analytical equation of energy change. It is demonstrated that the formation of the void nucleus is energetically favorable if the DhP radius exceeds some critical value. Besides, the void nucleus strives to gain the optimal size, corresponding to the energy change minimum. Theoretical results were analyzed taking into consideration the experimental observations.
This work was supported by the grant of Russian Science Foundation No. 19-19-00617.

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THE ANALYSIS OF FORCED VIBRATIONS OF A RECTANGULAR BEAM

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In our days, the search for solutions in the form of numerical expansion in the eigenvalue space is one of the most popular methods for evaluating the dynamics and stability of structures. The primary analysis of frequencies and modes of vibration is important, as it allows to avoid undesirable consequences in the design and operation of various structures. The analysis of the frequency of the driving force and its tuning from the main natural frequencies allows us to determine the initial dimensions of the structural elements.
In this paper, the study of free vibrations of a rigidly clamped beam of rectangular cross-section is carried out. In the ANSYS software package, the modal and harmonic analysis of beams under the influence of a harmonic driving force is performed and the solutions of the basic equations are compared. Using the Bernoulli-Euler beam model, the natural frequencies were determined analytically and the main forms of vibrations were calculated: bending, longitudinal, and torsional. Using the ANSYS software package, a finite element model of the beam was constructed and modal analysis was performed. For numerically obtained frequencies a comparison with the analytical solution was made. As a result of the study, mixed forms were identified, they could not be classified. These forms of vibration are also found in the operation of structures and have been studied in more detail. In the ANSYS software package, a harmonic analysis was performed: the effect that causes resonance at these frequencies was selected. The amplitude-frequency characteristics were constructed, the displacement and stress fields were obtained. Conclusions about accounting for such frequencies were made.

NONSTEADY HEAT TRANSFER: BALLISTIC TO DIFFUSIVE

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The problem of interrelation between ballistic and diffusive transfer mechanisms are studied on the base of simple mechanical models. The first model is a one-dimensional harmonic chain, where the bonds disappear if the deformation exceeds certain critical value and heals over if the deformation drops below the critical value (further: the chain with breaks). The kinetic description of this system is based on the analogy with the second model: a one-dimensional ideal gas, where barriers randomly appear and disappear (further: the gas with barriers). The barriers in the gas model mimic the bond breaks in the chain model; the mass transfer in the gas model is analogous to the heat transfer in the chain model.
For the gas with barriers a simple kinetic equation is derived and solved analytically. The solution demonstrates transfer between ballistic and diffusive transport mechanisms. In the diffusive limit the solution obeys square root time dependence of the transport rate common for classical diffusion. However, the shape of the fundamental solution differs from the Gauss curve that means that the diffusion is not of the Fourier type. The analytical kinetic solution is compared with the numeric solution of the chain dynamics for the unsteady problem of an instant heat disturbance, showing good correlation between kinetic and dynamics solutions.
The obtained results prove that the change of the heat transfer mechanism from ballistic to diffusive regime can be obtained in unsteady processes for the chains capable of dissociation at least for the certain time scales.

WEAR RESISTANT FE-BASED METALLIC GLASS COATINGS PRODUCED BY DETONATION SPRAYING

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Fe-based amorphous coatings with laminar amorphous structure and low porosity were fabricated via detonation spraying. The gas-atomized $Fe_{66}Cr_{10}Nb_5B_{19}$ feedstock powder with particle size 40-64 μm was partially crystallized. The deposition was conducted using acetylene-oxygen mixtures at an O_2/C_2H_2 molar ratio of 1.1 and explosive charges of 60% (fractions of the barrel volume filled with the gaseous mixture). The contents of the crystalline phase in the coatings were estimated from the XRD patterns, that shows crystalline phase content less 1 wt.%. $Fe_{66}Cr_{10}Nb_5B_{19}$ coatings showed high values of microhardness and wear-resistance under dry linearly reciprocating conditions. Notably, the wear resistance of the coating was higher than that of stainless steel. Morphological studies of the worn surface of the coatings indicated lamella detachment caused by the intrinsic structural features of the detonation coatings. This work demonstrated that the detonation spraying technology is suitable for manufacturing amorphous phase-based alloy coatings.

ALGORITHMIC MODELING OF THE HEART BASED ON CT SCANS

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According to the WHO, cardiovascular disease (CVD) is the leading cause of death worldwide. In 2008, an estimated 17.3 million people died from CVDs, accounting for about 30% of all deaths worldwide.
For early detection of various cardiological problems and further qualitative assessment of all risks, research, including CT scans, which record and analyze the internal structure of a person's organs, is necessary.
However, analysis of computer tomograms can be difficult: they can miss details, the physical size of organs can be underestimated, and there is no opportunity to practice the procedure before surgery. And obtaining a high-quality 3D model is accompanied by lengthy manual processing of images followed by heart printing.
The aim of this work is to write an algorithm that will allow in a reasonable time (not more than an hour) to simulate the heart (3D-body) based on CT-images, suitable for printing on a 3D-printer using software methods. Solving this problem will improve the quality of medical diagnosis and reduce additional risks before surgeries.
Initial data for the study is CT-images of the chest of a patient with cardiac pathology and confirmed diagnosis. During the work, a method of primary preparation of biomedical images was developed. And the developed algorithm

accelerates the process of modeling a 3D model of the heart, which is suitable for printing on a 3D printer and conveys the internal structure of the body.

RESERVOIR ROCK TREATMENT BY MECHANICAL WAVES

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The modern oil reservoir engineering requires artificial technologies on productive formation impact to maintain the production rates. Since the modern technologies of oil production leave more than a half of oil in place, increasing the recovery coefficient is one of the ways to maintain the production rates. This issue is relevant nowadays due to the fact that many oil fields are on the third and fourth stages of operation.

Several phenomena have to be considered while screening for an appropriate technology for oil production increase. Those phenomena are rheological features of the fluid flow through the formation, capillary forces and heterogeneity of reservoir properties of a productive formation in terms of thickness and area. Most of the known methods of impacting the reservoir cannot simultaneously take into account the above-mentioned phenomena and therefore have limited effectiveness.

Vibration wave action appears to be the most relevant technology [1, 2]. The technology does not change the structure of the formation pore space, does not require the use of special process fluids, consumables and is relatively inexpensive. It is proposed to act on the reservoir rock matrix by mechanical vibrations [3, 4].

In order to enhance the vibration wave impact on the formation zones not covered by the displacement front, the phenomenon of interference is used. To obtain the phenomenon of interference in the formation two point sources of mechanical vibrations have to be installed in the well. By changing the distance between the sources of vibrations, it is possible to move the area of occurrence of the interference pattern in the formation. To obtain stable interference, it is necessary to maintain the same frequency and constancy of the phase difference between the oscillations of the sources.

The conducted bench tests showed the positive effectiveness of the vibration wave impact on the change in interfacial tensions and rheological characteristics of formation fluids, on the change in phase permeabilities and on the change in capillary pressure. The use of two coherent sources of oscillations allowed to increase the depth of propagation of mechanical waves and the energy of mechanical action on the formation due to the occurrence of the interference phenomenon.

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NONEQUILIBRIUM THERMOMECHANICAL PROCESSES IN PERFECT CRYSTALS

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Recent experimental and theoretical works show that at nanoscale many conventional macroscopic constitutive relations are violated. In particular, significant deviations from the Fourier law of heat transfer are observed. Therefore development of new models describing thermomechanical processes at nanoscale is required. In this lecture, we will present a theory describing various nonequilibrium thermomechanical processes in perfect crystalline solids in harmonic approximation. In particular, we will focus on analytical description of approach to thermal equilibrium and unsteady ballistic heat transfer. Solutions of ballistic heat transfer problems will be used, in particular, for calculation of thermoelastic fields in crystals. In particular, we will show that combination of ballistic heat transfer and thermal expansion lead to emergence of new thermomechanical phenomena, such as the ballistic resonance. Additionally, we will discuss the influence of anharmonic effects and free boundaries on thermomechanical phenomena.

GRANULAR METAMATERIALS FOR SEISMIC PROTECTION

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The granular metamaterials for seismic protection utilize two principal ideas, (1) reflection of both P and S waves from an interface between the granular layer and ambient soil, and (2) dissipation of the wave energy inside the metamaterial. Both these ideas are verified by the constructed FE models revealing extensive reflection of S waves from the soil - granular metamaterial interface and energy dissipation.

RESPONSE OF FINE-GRAINED FIBER-REINFORCED CONCRETES UNDER DYNAMIC COMPRESSION

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Currently, new high-strength concretes and fiber-reinforced concretes are being actively introduced in the building structures industry. Metal and non-metal fibers which have adhesion along its surface to concrete are used for fiber-reinforced concrete. Fiber-reinforced concrete is recommended to be used for high-responsibility constructions. In such structures, the following technical advantages of fiber-reinforced concrete can be effectively used in comparison with traditional concrete: increased crack resistance, impact strength, fracture toughness, wear resistance, frost resistance and cavitation resistance, as well as reduced shrinkage and creep. To comply with the requirements of technical regulations in relation to fiber-reinforced concrete structures, the corresponding domestic set of rules are approved and enacted, which cover the area of static loading. At the same time, the area of dynamics of fiber-reinforced concretes not fully studied. In this regard, the report presents the results of dynamic tests of different types of fiber-reinforced concrete in comparison with concrete-matrix. The experiments were carried out using the split Hopkinson bar technique on samples of fine-grained concrete-matrix, as well as with the addition of metal, polymer fiber and its combination. Dynamic diagrams of deformation and dependences of maximum stresses versus the loading rate are constructed. The data obtained were used to determine the values of the incubation time of fracture of the studied materials.
The study was carried out at the expense of a grant from the President of the Russian Federation for state support of young Russian scientists No. MK-3526.2021.4 (Agreement No. 075-15-2021-256).

FOCUSING AND CUMULATION EFFECTS FOR THE INTERACTION OF SHOCK WAVES AND FAST-MOVING BODIES WITH GAS INHOMOGENEITIES

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A numerical study of the interaction of shock waves propagating in gases and the collision of blunt bodies flying at a supersonic speed with inhomogeneities - light or heavy gas bubbles of various density and chemical composition, including those filled with a reacting gas mixture was performed.
The phenomenon of shock focusing for the interaction of shock waves with gas bubbles of an ellipsoidal (in particular, spherical) shape was observed. In case of a low density (or light gas), the axial part of the shock wave is weakened and accelerated inside the gas bubble, and a zone of increased pressure is formed at the flow periphery from which a focusing toroidal shock wave propagates to the axis of symmetry. In the case of increased density (or heavy gas), the axial part of the shock wave is amplified and decelerated inside the gas bubble, while the peripheral part is refracted, bending around the bubble. Depending on the elongation of the bubble and the density of the gas inside it, specific modes are possible when the shock waves passing through and enveloping the bubble are focused in a very small volume - almost at a point. The focusing zone can be located outside or inside the deformed gas bubble, and in the latter case the highest pressure and temperature peaks in the focusing zone are achieved.
As an application of the observed focusing effect, the initiation of detonation by an incident shock wave in a gas bubble filled with a propane-air mixture with xenon additives is discussed. If the velocity of the shock wave exceeds a certain critical value determined by the composition of the mixture, detonation is directly initiated near the front interface of the

bubble. If the velocity of the shock wave is less than the critical one, it is possible to initiate detonation in high-temperature zones: at the periphery of a gas bubble at a triple point when the incident shock wave is refracted; or - on the axis of symmetry when the envelope and passing through the bubble shock waves are focused near its rear interface. The calculations performed for the selected gas composition show that due to the focusing effect, the Mach number of the incident shock wave, sufficient to initiate detonation, can be significantly reduced compared to the critical Mach number for direct initiation.
Another application is the occurrence of anomalous peak in pressure at the critical point of a blunt body in case of its interaction with gas bubble localized in the incident supersonic flow. It was found that the interaction of the bow shock wave with gas bubble corresponds to the described focusing scenarios, taking into account some specificity due to the presence of a body surface in the immediate vicinity of the focusing zone. For gas bubbles of low density, the pressure peak is caused by the action of a shock wave reflected from the curved rear interface of the gas bubble, significantly enhanced by focusing the toroidal shock wave. For gas bubbles of increased density, a significant factor is the effect of focusing in a small volume of the transmitted, envelope, and transverse shock waves, accompanied by the formation of cumulative jets and a high-pressure "gas breaker". To realize the maximum effect, the dimensions of the bubble should be of the order of the distance of the bow shock wave on the central streamline.
The results obtained can be used in the development of methods for influencing bodies moving in the atmosphere at supersonic speeds.
The investigations were carried out in the Institute of Mechanics of Lomonosov Moscow State University and were financially supported by the Russian Science Foundation (project 21-11-00773).

DISCRETE AND CONTINUUM APPROACHES TO DESCRIPTION OF HEAT TRANSPORT IN A SEMI-INFINITE FREE END HOOKE’S CHAIN

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Unsteady ballistic heat transport in a semi-infinite Hooke’s chain with free end is under investigation. The both cases of instantaneous thermal pulse and external heat supply are considered. Analytical descriptions of ballistic heat transport are proposed in the discrete and continuum formulations. Discrete solutions for the kinetic temperature are carried out by the eigenfunction decomposition method. It is shown that the both continuum and discrete descriptions for the far fields of the kinetic temperature are applicable. However, the continuum kinetic temperature is determined with error near the boundary even in a stationary state. At large times, the kinetic temperatures of the boundary have substantially different asymptotic behavior. A symmetry principle of continuum solution, which allows analyzing continuum problems for the semi-infinite Hooke’s chains through solutions for the infinite Hooke’s chains, is present. Formulation of this principle is based on an analytically discovered property of thermal waves to reflect from the free boundary.

TOWARDS MICROMECHANICS OF LOCAL FIELDS

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Enhanced understanding of processes in inhomogeneous structures is of great importance for science and practice. To date, the highest progress is reached in solving *homogenization* problems. These are problems concerning with evaluation of *effective modules*. The latter are defined mostly by *average* fields. Due to averaging, there is no need in accurate evaluation of local fields; effective modules are quite insensitive to these details. Commonly, even the simplest approximation of weak interaction between structural elements provides acceptable accuracy. In fact, this class of problems comprises the *micromechanics of average* fields.
There is another class of vital problems, which concern with *strength* and *safety*. They do require accurate evaluation of *local* fields with focusing on high *field concentrations*. The concentration is caused, first of all, by geometrical peculiarities, such as edges of blocks, corners, notches, crack contours, intersections of interfaces. In their vicinity, there arise initiation and accumulation of unfavourable processes, such as cracking, sparkling, corrosion, delamination, current discharge. The *extreme*, rather than average, values of fields (in particular, stresses) define the strength of a material. Clearly, finding extremes of local fields is much more involved than estimation of average values. It has become possible due to great progress in computers and computational methods. This rapidly developing class of problems arises as the *micromechanics of local* fields.
The work presents the state-of-art and results of the authors in this area. The results are partly published in the papers [1-6]. Specifically, we present (i) universal module evaluating the *exponent* of a local field; (ii) BIE, BEM and special boundary elements for evaluating *intensity factors* of local fields in strongly inhomogeneous media with multiple

interfaces of cracks, pores, inclusions, etc.; (iii) *improved* kernel-independent *fast multipole method*, which efficiently and without loss of accuracy solves the resulting systems with large number of DOFs, and (iv) methods of *extreme analysis* to properly estimate the strength and assign *safety factors*. The exposition is accompanied with examples and illustrated by numerical results.

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MODELING OF DOMAIN STRUCTURE EVOLUTION IN FERROELECTROELASTIC MATERIALS UNDER MONOTONIC AND CYCLIC LOADING

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Due to unique properties of ferroelectroelastic materials and introduction of new methods to improve their performance, such as composition engineering, morphotropic phase boundary, domain engineering, grain engineering, doping and texturing the number of engineering applications of these materials increases drastically. Consequently, extensive and accurate models of these materials are of great importance to increase the prediction quality of the nonlinear behavior of structures that carry ferroelectroelastic elements.

The direct mathematical modeling of the domain structure evolution in a single crystal based on the finite-element simulation and using micromechanical model is considered. The formation and movement of 90-degree and 180-degree domain walls is analyzed.

All 8 possible second rank laminate structures of ferroelectric domain patterns in tetragonal crystal system, that satisfy the compatibility conditions and coincide with the domain patterns reported in literature for the barium titanate has been studied. The dielectric hysteresis curves for representative volume elements of ferroelectric domain patterns in tetragonal crystal system under cyclic electric loading has been obtained.

The nonlinear boundary value problems for the representative volume element in cubic form are solved with applying mechanical and electrical periodic boundary conditions. The finite-element program PANTOCRATOR is used for the solution of the fully coupled electro-mechanical boundary value problem and for the homogenization procedure.

Results of computational experiments allows to reveal significant dependency of electromechanical properties, polarization and hysteresis curves of ferroelectric single crystal on the domain structure.

MODELS CHARACTERIZING NONLINEAR DEFORMATION AND FAILURE OF COMPOSITE MATERIALS

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The mechanical properties of many composite materials are not invariant to the loading condition but depend on the stress state, that is caused by heterogeneous structure of composite materials [1-2]. On the base of the analysis of results of experimental studies, an approach to the characterization of different nonlinear effects in the behavior of fibrous composite materials is proposed. One of them is concerned usually observed in experimental studies the dependence of deformation properties of composite materials on the type of external forces. To describe this effect, the corresponding constitutive relations are proposed where instead the matrix of constant anisotropic coefficients, the set of anisotropic functions is introduced.

Another type of nonlinearity lies in the fact that the shear stress-strain curves are nonlinear and the curvature of diagrams depends on the extent of shear strain, though they are linear ones when the load is applied along the reinforcement. To describe this effect, the additional scalar parameter is introduced into the constitutive relations that is related with a matrix characterizing the shear deformation.
The third type of nonlinearity is concerned the damage evolution and its influence on the stiffness characteristics that determines the fracture properties of composite materials. To describe the damage accumulation process, the system of general failure model assumptions is formulated that include the choice of first ply failure criterion, constitutive relations for damaged materials with the use of corresponding damage parameters and other effects. These models are implemented into Abacus and numerical simulation of structural members are carried out. A good correspondence between theoretical dependencies obtained on the base of proposed models, numerical simulations and the results of experimental studies is shown.
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EXTENDED SYSTEM OF SEMI-EQUIVALENT FORMULATIONS OF BOUNDARY VALUE PROBLEMS OF GRADIENT ELASTICITY, CHOOSING PROBLEM OF REALIZED BOUNDARY CONDITIONS

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Variational the high-order models of mechanics of deformable media are considered, which are formulated in displacements, where the list of arguments is extended compared to classical elasticity and includes not only displacements, but also, in the general case, derivatives of displacements along coordinates of the first and higher orders. Further in the work we consider the linear second order gradient models of elasticity, for which it is assumed that the potential energy density for reversible processes makes it possible to unambiguously establish the physical (constitutive) relations using the extended Green's relations and completely determines the boundary value problem, i.e. equilibrium equations in the volume of the body, boundary conditions on the surface of the body, and boundary conditions on the edges in the case of a piecewise smooth surface of the body. This is established using standard techniques, which are reduced to the procedure of integration by parts within the framework of variational approaches. Many well-known mechanics consider the ability to formulate boundary conditions on edges as one of the essential advantages of gradient theories. In our work, we seem to be the first to point out that for a specific structure of potential energy density, there is a family of boundary value problems, i.e. an apparent non-uniqueness arises. It is shown that for models of a higher order and the same structure of potential energy density, variational methods make it possible to formulate a wide range of boundary value problems, which significantly expands both the spectrum of solutions to applied problems and the spectrum of physical interpretation of these problems. We will call such variational formulations semi-equivalent. In particular, among the class of this kind of alternative formulations, there may exist, as a rule, models that are simpler to implement, in which, as in classical elasticity, the boundary conditions are formulated only on the surface of the body and it becomes possible to avoid the formulation of boundary conditions on the edges. As a result, when solving applied problems, the problem of choosing solutions arises due to the appearance of this type of non-uniqueness, because alternative formulations are actually reduced to the implementation of boundary conditions of different rigidity. To solve this problem, it is proposed to use the criterion of the minimum potential energy density. Examples of the existence of alternative formulations of several variants of gradient models - the model of the interphase layer, “vector” gradient models, and the gradient dilation model of elasticity are given. Examples of alternative solutions to specific applied problems and their comparison are given.
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CONTACT INTERACTION OF A SYSTEM OF RIGID PUNCHES WITH AN ELASTOPLASTIC HALF-PLANE

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The problem for contact interaction of a system of rigid punches with an elastoplastic half-plane is relevant for many applications. Despite its classical formulation, it cannot be solved by elementary methods because of the non-linearity involved by plastic effects. In present work a methodology for numerical-analytical solution of the plane contact problem for a system of rigid punches with a elastoplastic half-space is developed.
Within proposed methodology, the displacement and stress distributions before the onset of plastic deformation are defined analytically. The solution of correspondent boundary value problem is obtained by the Hilbert-Privalov conjugation method. The continuation of numerical simulation and analysis of the evolution of plastic deformations is provided with finite element method. The numerical algorithm is based on the augmented Lagrangian method, with the initial distribution of stresses and displacements taken from the analytical solution for the elastic contact problem. Inelastic deformation are considered in the formulation of ideal plasticity (according to the Mises criterion) and, alternatively, in the formulation of the theory of linear hardening. As a result, displacements and stresses, as well as the evolution of contact zones and the regions of plastic deformation, are obtained according to the parameter of loading. To verify the algorithm of the numerical-analytical solution, test calculations were performed for one rectangular stamp with and without slip. The results were compared with the data known from the literature.
A qualitative analysis of the impact of hardening on the nature of the evolution of zonal deformation was carried out. To understand the mutual influence of the stamps, a computational analysis of the evolution of stresses and contact forces was performed. The simultaneous indentation of three rectangular stamps was simulated. The results of the computational simulations indicate that if the distance between the punches is of the same order as the length of their contact zone, then the mutual influence significantly changes the stress fields in comparison with the stresses obtained by the superposition of solutions for individual punches.
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HIERERCHICAL MODELS FOR THE COUPLING OF DETAILED CHEMICAL KINETICS WITH MOLECULAR TRANSPORT AND FLOW

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The evolution of the vector of scalars (enthalpy, pressure, species concentrations) of a reacting flow is governed by a partial differential equation system. The description of chemically reacting systems (e.g. combustion, chemical processes in the atmosphere, or biological systems) leads very often to reaction mechanisms with far above thousand chemical species (and, therefore, to more than thousand partial differential equations), which possibly react within more than several thousands of elementary reactions. These kinetic processes cover time scales from nanoseconds to seconds. Due to these scaling problems the detailed simulation of three-dimensional turbulent flows in practical systems is beyond the capacity of even today's high performance computers. Using model reduction concepts is a way out of this problem.
Both the chemical source term and the molecular transport term have one important property, namely that they cause the existence of low-dimensional attractors in state space (the space spanned by the thermokinetic variables). These manifolds can be parameterized by a small number of variables, and the original evolution equation can be projected onto those low-dimensional manifolds.
In this work we discuss several model reduction aspects based on the concept of low-dimensional manifolds, namely the efficient identification of the low-dimensional manifolds (e.g., reaction diffusion manifolds - REDIM, intrinsic low-dimensional manifolds – ILDM, global quasilinearization - GQL) the efficient implementation to simplify the chemical kinetics, the hierarchical nature of the low-dimensional manifolds, and the use of the model reduction in reacting flow calculations.

MAGNETOELASTIC WAVE IN DAMAGED MATERIAL

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A longitudinal magnetoelastic wave in a rod is studied taking into account the damage of its material. The analysis shows that low-frequency disturbances have a pronounced frequency-dependent dissipation and dispersion proportional to the frequency radical for any values of the damage parameter. High-frequency disturbances, for the post-threshold values of the damage parameter, propagate practically without dispersion, and the attenuation takes on a constant value, independent of frequency. At subthreshold values of the damage parameter, high-frequency disturbances have a constant wavelength, i.e. the speed of propagation of the disturbance does not depend on the frequency, and the damping increases linearly with increasing frequency. A change in the damage parameter can lead to the existence of both normal and anomalous dispersions. In the absence of damage, anomalous dispersion appears over the entire frequency range. The presence of damage in the range of subthreshold values close to the boundary value makes it possible to obtain normal dispersion in a limited frequency range. For postthreshold positive values of the damage coefficient, anomalous dispersion is observed only at low frequencies. It is determined that the balance between elastic nonlinearity and dissipation caused by material damage can lead to the formation of a localized weak shock wave of deformation. The width of the shock wave will increase, and its velocity will decrease with an increase in the parameter characterizing the damage to the material.
This work was carried out with the support of the Russian Science Foundation (grant No. 21-19-00813).

WIRELESS ECG MONITORING DEVICE WITH THE ABILITY TO COLLECT AND ANALYZE THE RECEIVED DATA

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The paper describes an invention from the field of preventive medicine. It is based on a battery-powered electrocardiogram (ECG) monitor and a built-in signal processor. The patient wears the device on the body in the area of the heart. Fixation is made using a silicone substrate with holes for electrodes. On top of it is an additional flexible plastic mount for the battery and the electronic board. The silicone backing is attached to the body with medical grade glue. The received signal is filtered and aligned using a discrete wavelet transform. Approximating and detailing coefficients are allocated. They are used to reconstruct the received signal without high frequency components. PQRST waves are extracted from the received cardio signal by using approximating wavelet transform coefficients. Further processing and analysis take place on the patient's smartphone. This invention allows you to collect data over a long period of time and identify rare arrhythmias. The device has an emergency notification system when the received ECG deviates out of range.

IMPACT ON THE DISPERSIVE WAVE DUE TO IMPULSIVE POINT SOURCE AT THE INTERFACE OF ANISOTROPIC PORO-ELASTIC LAYER AND NON-HOMOGENEOUS INFINITE EXTEND MEDIUM

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The work is concerned with the impact on the surface type dispersive wave due to the impulsive point source at the interface between a homogeneous coated poro-elastic layer over an anisotropic non-homogeneous half-space. The novel aspect this study is made to investigate the nature of the surface wave scattering due to the point source within it when the upper surface of the porous medium is coated by a thin isotropic-homogeneous layer. The study is claimed that presence of coated layer to the top of the model, controls\protects the intensity of the earthquake in the form of the phase velocity or group velocity. The Green's functions and Fourier transform approaches are implemented to calculate the closed form solution of the dispersive wave. Further, the complex form of wave number is introduced on the dispersive wave to separate-out the damping of the phase velocity and calculate the corrected phase velocity equation. The velocity of energy transport in the form of group velocity wave is obtained from the main dispersive equation. Theoretical validities of original dispersive wave examined in some particular cases. The impact of different parameters, involved in the model, is analysed numerically from dispersive wave and illustrated graphically. The results of the study may find applications in exploration geophysics, civil engineering and Biomedical.

3D MESHLESS VORTEX LOOPS METHOD WITH IMPROVED APPROACH TO THE BOUNDARY INTEGRAL EQUATION SOLUTION

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A new approach is developed for incompressible 3D flow simulation around bodies by Lagrangian vortex method. Closed vortex loops are considered as vortex elements, which are generated on the body providing satisfaction of the boundary condition on the body surface. The developed algorithm makes it possible to improve significantly the quality of solution for the complex-shaped bodies with low-quality surface meshes. The combination of this approach with vortex wake modeling with vortex loops allows to simulate unsteady flows with acceptable computational complexity.
The body surface is replaced with vortex sheet of unknown density, which in turn, can be considered as a surface gradient of the double layer potential density. The developed T-scheme makes it possible to solve the problems for bodies of complicated shape with unstructured surface mesh containing cells with high aspect ratio. In addition, the bodies often have small details, and this approach allows for mesh refinement and working with non-uniform meshes correctly.
The other problem is connected with simulation of the vortex wake in the flow domain, which is formed behind the bodies. A modern approach is implemented, according to which vorticity (both in the flow domain and on the body surface) is represented as closed vortex loops, and all the loops have the same strength (circulation). The positions of the loops generated on the body surface coincide with the double layer potential level-set lines. The procedure of the double layer potential density reconstruction is also developed.
The considered test problems show that the developed algorithm (the T-scheme) makes it possible to improve significantly the quality of solution for the complex-shaped bodies with low-quality surface meshes. Its accuracy is approximately 10 times higher in comparison to traditionally used N-scheme, which is based on the boundary condition satisfaction with respect to normal velocity component.

INSECTOMORPHIC ROBOT RESCUE FROM AN EMERGENCY ON THE BACK UNDER THE INTERFERENCE OF INFLUENCE

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The new problem of rescuing an autonomous insectomorphic robot from the abnormal upside down position is solved. As a supporting surface, we consider a horizontal plane and an inclined plane with a slight slope towards the flip. In both cases, there may be a pit optionally with a bump next to it in the place of the initial contact of the robot with the support. To make the rescuing operation possible, a special shape of the robot's body consisting of two truncated right circular cylinders put together by their common plane rectangular cut is proposed. An algorithm for rocking the robot in the neighborhood of its emergency equilibrium position is developed. This algorithm uses the robot's kinematic and dynamic capabilities to bring the robot to normal position without outside assistance.
The legs on the pre-chosen edge of the body through which the flip should occur, are passive, and straightened along the body so that they do not interfere with the flip. The legs on the opposite edge are active; they perform synchronous movement in a plane perpendicular to the longitudinal axis of the body, with a fixed angle in the knee [1].
The validity of the algorithm is justified analytically for the case of the horizontal plane [1]. A stable resonance motion of the system that turns the robot over to normal working position is designed.
This work develops the previous results presented in [2, 3] in what concerns algorithms of six-legged walking robot's motion control in emergency situations.
The algorithms proposed in this work were verified using computer simulation in a software environment implementing the computation of the interaction of the complete three-dimensional dynamic model of the system consisting of the robot interacting with the support [1]. Universal Mechanism software package [4] was used to perform the computer experiments. The analytical analysis of a simplified dynamics of the system helped find constraints on the application of the proposed method due to geometric and mass characteristics of the robot design [1].
The specifics of swinging due to the slope, the pit and the bump were worked out using computer simulation and are presented. They consist in the fact that the changes of the mass of legs and the angles of the maximum deviation of the active legs are needed. Approximate sizes of the pit and the bump through which robot can roll over are specified for the chosen typical mass and geometric parameters of the robot.
This work was supported by the Russian Foundation for Basic Research (grant no. 19-01-00123 A).

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STUDY OF THE EFFECT OF THE RAIL WELDED JOINT GEOMETRY ON THE CONTACT INTERACTION IN WHEEL-RAIL SYSTEM

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While passing the welded joint the rail and the wheel suffer from great dynamic loads, which lead to the damage of the rolling surface of the rail head and the wheel, in particular, crushing, shelling and spalling. The aim of the research is to study the influence of geometry of deformed rail surface in the heat effected zone of rail welded joint (the irregularity) and the contact conditions of the wheel/rail system (the rolling velocity, the sliding friction coefficient) on the contact stresses distribution and the friction force [1].

In this study the three-dimensional contact problem for rolling of the wheel over the rail surface after the collision with the irregularity is considered. In rolling the contact region consists of stick and slip subregions, which configuration is unknown in advance. The relation between normal and shear stresses in the slip subregions is described by the Coulomb-Amontons' law. It is assumed that the elastic properties of the wheel and the rail are similar, and the Hertz solution for elliptical contact area is used to calculate the normal stress distribution in contact region. We consider that during the first few contacts of the wheel with the rail welded joint, plastic deformations occur, then the material of the rail hardens and only elastic deformations remain during the following contact interaction cycles. The contact shear stress is determined with the variational method and the gradient projection method [2]. The influence of the rolling velocity of the wheel, the sliding friction coefficient and parameters of the irregularity on the contact shear stresses and the friction force were studied. The results of the study will be used to develop the model of the wheel-rail interaction in the area of rail welded joint, taking into account the geometry of the rail surface in the welded joint area and the dynamic loads.

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SIMULATION OF A DETONATION ENGINE ON AN ACETYLENE-OXYGEN MIXTURE

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Rotating detonation wave combustion chambers investigation is at the forefront of new types of engine research. The expected increase in efficiency, the simplicity of the design without the need for mechanical actuation, and the ease of assembly make them particularly attractive. This promising technology can be integrated into existing architectures of power plants and power generation.

In this paper, a three-dimensional numerical simulation of a combustion chamber with a rotating detonation wave was carried out; the shape of the chamber was a cylinder with an internal body. The fuel supply was carried out both from the end part (the system of injectors or the slot) and from a perpendicular system of injectors on the inner wall. The combustible mixture was acetylene with oxygen. To describe the kinetics of acetylene combustion, we used a simplified chemical kinetic scheme of 10 components and 13 reactions. The process of starting an engine initially filled with air under normal conditions in the combustion chamber and low external pressure was investigated. The influence of the length of the combustion chamber annular channel on the stability of the detonation wave and traction characteristics

was studied. The author's computer code based on the model of multicomponent gas dynamics with chemical transformations and turbulence was used in the simulation. The code was tested by comparing it with experiments and analytical solutions for simple cases. For detailed visualization of the obtained results, the author's visualization system was used, designed for graphical processing of large data calculations.
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MATHEMATICAL AND FINITE ELEMENT MODELING OF THE RECONSTRUCTED HUMAN MIDDLE EAR

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Mathematical and finite-element models of the human reconstructed middle ear subjected to different variants of tympanoplasty and ossiculoplasty are presented. The theories of thin isotropic and anisotropic layered plates are used to simulate mechanical behavior of the reconstructed tympanic membrane in the case of utilizing the "cartilage plate" and "small island" techniques for the tympanoplasty. When developing the mathematical models, the prosthesis inserted between the repaired membrane and the stapes as well as intact ossicles are considered as solid bodies. The finite-element models of all basic elements of the oscillatory system as well as of tendons, ligaments, and muscles are constructed in accordance with their anatomical structural specificities (the membrane three-layering, inhomogeneity of ossicules, etc).
The static mathematical model allowed estimating initial stresses arising in both the reconstructed eardrum and the prosthesis-stapes coupling and showed that the inserted prosthesis replacing the "malleus-incus" chain may take different stable positions corresponding to the minimum potential energy of the biomechanical system. The implementation of the mathematical dynamic models revealed that the reconstruction technique anticipating the total replacement of the eardrum with a cartilage implant and the installation of the "T-type" prosthesis can result in appearing the so-called "dead modes" which are vibrations of only the eardrum without simulation of the attached prosthesis motion. The finite-element models of the middle ear with the retraction pocket at the tympanic membrane as well as with a cartilage graft covering the perforated place of the diseased eardrum are also presented in our study. The optimal geometric parameters of the cartilage graft, providing sound conductivity of the reconstructed middle ear oscillatory system corresponding the auditory functions of the normal middle ear are estimated. In particular, it was revealed that the optimal thickness of the graft overlapping the posterosuperior quadrant after removal of the fixed retraction pocket is about 0.193 ± 0.031 mm.
The outcomes obtained can be used in planning surgical operations to restore the integrity of both the tympanic membrane and the entire middle ear and improve auditory conduction.

ON STABILITY OF PROPAGATING CHEMICAL REACTION FRONTS IN ELASTIC SOLIDS

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This work focuses on studying kinetics and stability of chemical reaction fronts in elastic solids. The reaction between solid and diffusing constituents is localized at the chemical reaction front, i.e., a sharp interface which separates transformed and untransformed materials. A diffusing constituent is delivered through the transformed material to the reaction front where the reaction occurs. A chemical transformation is accompanied by the transformation strain, and emerging mechanical stresses can accelerate, retard, or even block the reaction front propagation.
Kinetics of the reaction front is modeled utilizing a chemical affinity tensor concept (see [1] and reference therein), which couples mechanical stresses and a chemical reaction rate. The propagating reaction front can be either stable or unstable. In this work, an analytical linear stability analysis of the propagating reaction front is carried out for an axially symmetric interface in the case of linear elastic solid constituents. The procedure is based on the equilibrium phase interface linear stability analysis [2] and allows to study the stability of the reaction front in the blocking state as well as of the propagating interfaces. The growth or decay of perturbations is studied numerically, using FE simulations with remeshing algorithms [3]. The competition between the global kinetics of the interface and local kinetics of the perturbation evolution is discussed.
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NONLINEAR DYNAMICS OF ELECTROSTATIC COMB-DRIVE WITH VARIABLE GAP

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There are many types of microelectromechanical system actuation: electrostatic actuation, piezoelectric actuation, temperature actuation, magnetic actuation and so on. Electrostatic actuation is a most commonly used version because it is easy in implementation and compatible with CMOS circuits. It’s based on electrostatic attractive forces on plates with opposite sign electric charges and can be classified on two subtypes – perpendicular and parallel driving relatively to plane of electrodes. An advantage of variable gap actuator in comparison with variable area ones lies in value of created electrostatic force – with changing gap it’s bigger. However, the disadvantage of such systems is limitation on displacement of movable electrode – when it will exceed the value equals one third of gap, the pull-in effect would perform and system would break down.

This paper is dedicated to investigation of nonlinear dynamics of electrostatic comb-drive with variable gap. Due to the fact that electrostatic force is in nonlinear dependence on movable electrode displacement, the investigation of the system is provided by approximate asymptotic methods of nonlinear dynamics, in particular, multi-scale method and methods of continuation theory. In paper the amplitude-frequency response and amplitude-force response were obtained for various values of parameters of elastic suspension’s nonlinear force, DC and AC constituents of electrostatic force amplitude. The area of parameter’s values, in which comb-drive will provide a required amplitude of vibration, is obtained. An influence of second stationary electrode on dynamic of the system is appreciated. Also, case of parametric excitation of vibration when movable electrode is at the same distance between two stationary ones is explored.

THERMAL AND DIFFUSION PROCESSES IN ONE-DIMENSIONAL CRUSTAL

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It is a difficult problem to develop an exact analytical model of non-stationary thermal and diffusion processes observed at the molecular level. So far, it has been done only for a limited group of systems. Considerable progress has been achieved for harmonic crystals[1,2,3] with linearized atomic interaction forces. Such an approximation is justified if the temperatures are far from melting points and the electronic subsystem does not significantly contribute to the overall dynamics of the crystal lattice. These conditions are naturally satisfied for covalent crystals. In the present paper, we analyze non-stationary thermo-diffusion processes in finite systems on the example of a one-dimensional harmonic crystal. Thermal processes are those involving random velocities of crystal particles and diffusion processes involve random displacements.

There are two types of thermal processes in crystals: fast and slow[4]. Fast processes are transient and are associated with energy redistribution between degrees of freedom, and slow processes are associated with heat transfer. In this work, we will focus on fast processes only, so that the system state can be regarded as spatially uniform. Current technologies used to generate and measure ultra-short laser will make experimental studies of such processes possible in the near future. Additionally to thermal processes, the related diffusion processes are considered. No changes of particle order occur in a harmonic crystal, so the diffusion as particle mixing does not exist. However, a particle can move away to significant distances from its initial position as a result of thermal motion, so the corresponding diffusion processes are rather complicated and differ significantly from thermal processes. In particular, as we will show later, both fast and slow processes are realized for diffusion in the spatially uniform case.

The study of systems containing a finite number of atoms[5] becomes especially relevant with nanotechnology development. Thermo-diffusion processes in such systems have several specific features related to their finite nature. In particular, the work will demonstrate that fast thermal processes in the finite crystal periodically spontaneously recur. That is called the ``thermal echo''. Because of the slow diffusion processes the system returns to its initial state in time with an order of magnitude of the sound wave passing the crystal.

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SIMULATION OF INELASTIC RESPONSE OF POLYCRYSTALLINE NICKEL BASED ON MICROMECHANICAL MODEL HOMOGENIZATION

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Ensuring of the durability and safety of critical structural elements leads to the necessity of increasing the accuracy of the stress-strain state determining, and, as a consequence, to the development and use of improved inelastic material models. One way for a more accurate description of the inelastic behavior of materials is to use of micromechanical models, accounting real physical processes at micro- and meso-levels.

The aim of the study is to describe the inelastic response of polycrystalline nickel under complex multiaxial passive loading (inside yield surface), which is relevant for the fatigue durability estimation. Full-field homogenization has been carried out using the finite element method to solve the governing partial-differential equations of micromechanics for the cubic representative volume element of the polycrystalline material. The rate independent crystal plasticity micromechanical model is used in the simulations. This model takes into account the process of plastic deformation by crystallographic slip and provides an accurate and physically-based representation of this phenomenon at the microscopic level within each grain.

The simulations have been performed with help of the finite-element program PANTOCRATOR. The considered representative volume element of the polycrystalline material consists of a multitude of single crystals, the total orientation of which is determined by uniform distribution within the full solid angle. The influence of the partition of the representative volume and the number of single crystals in the model were investigated. Various types of boundary conditions were considered.

Comparison of the simulation results using the proposed homogenized micromechanical model demonstrates a good agreement with the results of experiments on the polycrystalline nickel tube specimens under complex non-proportional combined tension and torsion.

NUMERICAL HOMOGENIZATION OF POROUS NONUNIFORMLY POLARIZED PIEZOCOMPOSITES BY USING 3-0 ALGORITHM OF ACELAN-COMPOS PACKAGE AND EFFECTIVE MODULI METHOD WITH VARIOUS TYPES OF BOUNDARY CONDITIONS

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In present work we have developed the effective moduli method and finite element technique for homogenization of porous nonuniformly polarized piezocomposites. Theoretical aspects of the effective moduli method for inhomogeneous piezoelectric media were examined. Four static piezoelectric problems for a representative volume that allow finding the effective moduli of an inhomogeneous body were specified. These problems differ by the boundary conditions which were set on a representative volume surfaces: mechanical displacements and electric potential, mechanical displacements and normal component of electric displacement vector, mechanical stress vector and electric potential, and mechanical stress vector and normal component of electric displacement vector. Respective equations for calculation of effective moduli of piezoelectric media with arbitrary anisotropy were derived.

Based on these equations the full set of effective moduli for porous piezoceramic composite having wide porosity range was calculated with help of finite element method realized in the ANSYS package and in the new software ACELAN-COMPOSE. Pores were modeled by using 3-0 “granule” algorithm in ACELAN-COMPOSE package with the option of no pores on the border. Then, the representative volume models generated in ACELAN-COMPOS were transferred to the ANSYS finite element package, where the effective moduli of the composite were calculated.

Here, we also simulated the nonuniform polarization field around the pore. For taking this effect into account, we previously solved the electrostatic problem for a porous dielectric material with the same geometric structure. From this problem, we obtained the polarization field in the porous piezomaterial; and after that, we modified the material properties of the finite elements from dielectric to piezoelectric with element coordinate systems whose corresponding axes rotated along the polarization vectors. As a result, we obtained the representative volume with inhomogeneously polarized piezoceramic matrix.
The computational experiments carried out have shown that all the considered four variants of the boundary conditions can be used in homogenization problems, since they give rather close results. Taking into account nonuniform polarization is important for precision modeling of porous piezocomposites, especially with complex pore structures and high porosity.
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CALCULATION OF THE STRESS LEVEL AT THE SIMULATION OF THE INTERACTION OF DISLOCATION IN ALUMINUM BRONZE

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Molecular dynamics modeling allows us to consider the motion and interaction of dislocations in crystal structures. Modeling of the deformation of single crystals of aluminum bronze was carried out using the LAMMPS software package and the interparticle potential constructed in the framework of the embedded atom method. In this work, dislocation complexes were systematized, which carry out sliding along with single partial dislocations. Slow dislocation complexes, which are slip barriers, have been identified. It was found that the movement of the dislocation complex from one cluster to another coincides with the section of the stress drop on the stress-time curve. If no movement of dislocations between clusters is observed, then an increase in stress is observed in this section. Thus, the alternation of areas of hardening and softening on the stress-time curves is associated with the dynamics of changes in the dislocation structure under load: the slip of dislocation complexes between dislocation clusters.
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WAVE PROPAGATION IN MICROSTRUCTURED MEDIA FOR NONDESTRUCTIVE TESTING

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Incorporating the role of microstructure into linear wave propagation leads to a number of interesting nonclassical features, such as Rayleigh and bulk wave dispersion, existence of antiplane Rayleigh waves and novel wave diffraction. We give an overview of these phenomena and present nonclassical results for localized waves, namely Stoneley and Love waves. We show that the former exist under much broader conditions, in contrast to classical Stoneley waves which are more the exception than the rule. Microstructure also affects Love waves, and it leads to different propagation scenarios according to the relative properties of the adjoining materials. Such features may be of great value for determining microstructural features by nondestructive testing (NDT). Indeed, propagation bands appear whose limits are defined by an explicit condition. Such condition may be put to advantage to infer material properties from Love wave propagation. Since the inverse propagation problem is inherently nonlinear, looking for other observables greatly helps mitigating the danger of solution nonuniqueness. In fact, we show that the Love propagation condition is a combination of Rayleigh and Rayleigh-Lamb propagation conditions, whence determination of either provides the missing data for a unique reconstruction.

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SEPARATION OF EMULSIONS UNDER THE ACTION OF AN INHOMOGENEOUS ALTERNATING ELECTRIC FIELD

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The separation of emulsions in the oil industry is a technological problem. The problem of separation of oil emulsions is the presence of asphaltenes, resins, and paraffins on the interfacial surface, which increase the stability of the emulsion. A promising method for the separation of oil emulsions is electrical action, in which there is no use of chemical reagents.
The effect of an inhomogeneous electric field on an emulsion of the "water in oil" type is studied in this paper [1]. The inhomogeneity of the electric field is created deliberately with the help of a special geometry of the microelectrode system. The main purpose of this work is to study the dynamics of coalescence of emulsion droplets. The object of the study is water droplets suspended in tetradecane, which are stabilized by the surfactant Span 80. To study the effect of the electric field on the emulsion, an experimental setup was assembled, the main part of which is the experimental cell. As the lower substrate of the cell, glasses with an electrically conductive layer of indium tin oxide ITO (Indium Tin Oxide) are used. On a surface etched with saw tooth-shaped electrodes with a distance of 200 microns between the vertices by photolithography. The experimental cell was placed on the slide table of the optical microscope IX71 (Olympus). An alternating bipolar voltage was applied to the electrode system from an arbitrary waveform generator 33522A (Agilent Technologies), amplified by a Tabor 9100 amplifier (Tabor Electronics Ltd.). The amplitude of the applied voltage varied in the range from 75 to 300 V, and the frequency from 0.05 to 15 kHz. The process of exposure was recorded using a high-speed camera FASTCAM SA5 (Photron) at a frequency of 250 frames per second. Images of the microstructure of the emulsion before and after exposure to an electric field were selected from the resulting video sequence.
It was found that the main changes in the microstructure of the studied emulsion occur in a fraction of a second, regardless of the frequency and voltage of the applied field as a result of the studies. The emulsion droplets were evenly distributed in the cell prior to exposure. When the electric field is turned on, water droplets begin to move in the region of the interelectrode space, where they collide and coalesce (coalesce), which leads to the formation of larger droplets. The results of the experimental studies have shown that with an increase in the voltage of the applied electric field, the effect of coalescence increases.

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DEVELOPMENT OF A MODEL FOR SHORT-TERM PRODUCTION FORECASTING BASED ON A HYBRID PROBABILISTIC APPROACH

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The purpose of this work is to create and test a computational tool for the forecast of production for each well, taking into account the conducted and planned geological and technical measures (GTM). This goal was achieved by using a hybrid probabilistic model, which is composed of an ensemble of models of different nature: non-stationary filtering, material balance and machine learning models. The key feature of the developed tool is the possibility of fully automated adaptation to the operation history of each well in a reasonable time.
The developed computational tool makes it possible to quickly obtain a short-term forecast of liquid and oil production considering a priori information (for example, hydrodynamic studies), while the forecast can also be made in the form of a confidence interval with a given confidence level. A feature of the developed solution is the potential possibility of correct processing of changes in the well and reservoir parameters in the simulation process after GTMs.
Tests conducted for both synthetic and real-world data have demonstrated the model's robustness and potential for engineering applications related to the need to forecast oil production.

SELF-SYNCHRONIZATION OF INERTIAL VIBRATION EXCITERS IN A SYSTEM WITH AN ELASTIC LIMITER

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The work is devoted to the problem of ensuring stable vibrations of vibration technological machines excited by self-synchronizing inertial exciters, which operate near the resonant frequency. A planar single-mass model of a vibration machine on a linear elastic suspension and with an additional elastic limiter installed with a certain initial clearance in relation to the working body is considered. The interaction of the machine's working body with the technological load is taken into account using added mass and viscous friction forces proportional to the mass of the technological load. Vibrations of the machine are excited by two unbalance vibration exciters rigidly fixed on the working body and driven by asynchronous electric motors supplied through a single power source. The modes of the working body vibrations and the self-synchronization of vibration exciters, depending on the change in the mass of the technological load, have been analyzed by numerical simulation methods. It is shown that, near the resonant frequency range, the introduction of an elastic limiter into the system can significantly reduce the sensitivity of the working body's vibration amplitudes to changes in the technological load, as well as leads to stabilization of the mutual phase of vibration exciters rotation and expansion of the frequency range of stable operating modes.
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COUPLED MODEL OF DEEP-BED-FILTRATION AND CAKE FILTRATION IN POROUS MEDIA FOR GRAVEL PACK MODELLING

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Gravel packs are widely used as sand control method. However, particles clogging and cake growth may cause significant decrease in well productivity. The article deals with the problem of mathematical modelling of suspension filtration in porous media of gravel packs. The coupling of deep-bed filtration and cake filtration is proposed. Mathematical model is based on mass balance equations and Darcy's law. Much attention is given to the description of cake behavior using averaging procedure. Numerical solution is found by finite-difference method. The good agreement between considered mathematical model and experimental data is reached. It should be also noted that particle size distribution is taken into account in boundary conditions. The dependence between permeability reducing and sand concentration passed through porous media is investigated. In case of using small gravel particles filter's permeability strongly reduces due to cake growth. Much attention is also given to analysis of permeability's dynamics for different gravel size/grain-size ratio. Overall, proposed coupled mathematical model of gravel pack allows to determine gravel sizing criteria more accurately than classical methods.

STUDY ON APPLICATION OF TANGENTIAL JET BLOWING ON ADAPTIVE HIGH-LIFT WING

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Adaptive high-lift wing, which includes a single-slotted flap and a spoiler droop (adaptive element), is an effective means of controlling aerodynamic characteristics in take-off and landing flight modes and is increasingly, used on modern transport category aircraft. However, when the flap is deflected at large angles, it is also necessary to optimize the gap height to ensure flow without separation over its surface by significantly deflecting the spoiler down. As a result, there is a flow separation over the trailing part of the wing upper surface, due to a sharp increase in curvature, which reduces the efficiency of the wing high-lift devices.
In this paper, the application of tangential jet blowing on the adaptive element to suppress the flow separation on its surface is considered. Numerical studies were carried out in a two-dimensional setting on the wing airfoil with fixed deflection angles of the Kruger flap of δ_K=25° and the flap of δ_F=45°. The adaptive element with a slot nozzle was deflected at angles of 16° and 20°, providing a change in the relative gap height between the flap and the wing trailing edge from 2 to 1%. The option of deflecting the spoiler droop by δ_{SD}=20° completely covering the gap between the flap and the wing trailing edge was also considered. The blowing momentum coefficient $C\mu$ was ranged from 0 to 0.1 at fixed Mach number M=0.15 and Reynolds number $Re=2\cdot10^6$. The angle of attack in the calculations was α=5º. The

computational fluid dynamics (CFD) program based on the solution of the Reynolds averaged Navier-Stokes equations (RANS) was used for the calculation.
It is shown that jet blowing with momentum coefficient of $C\mu=0.025$ augments the lift coefficient by suppressing the flow separation on the adaptive element and the super circulation. An increase in the intensity of the jet blowing to $C\mu=0.04$ allows increasing the value of the lift coefficient by approximately 35-50%, and at the same time, by suppressing the separation of the boundary layer on the flap, the drag coefficient is reduced. Flow patterns and features of the interaction between the blown jet and the flow near the slotted flap are shown. Computational studies have shown that the tangential jet blowing on the adaptive element is an effective way to increase the aerodynamic characteristics of adaptive high-lift wing.

UNIDIRECTIONAL SYNCHRONIZATION UNDER COMMUNICATION CONSTRAINTS

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As discovered by Christiaan Huygens, the coupled dynamical systems can demonstrate a coherent behavior, usually referred to as the synchronization. This remarkable phenomenon can also be observed even in situations when the individual dynamics exhibit sensitive dependence on initial conditions, that is, each dynamics taken alone is chaotic. In this talk we focus on a situation when the dynamical systems are interconnected via a communication channel with a limited transmission rate. We pose and answer the following question: how fast the data have to be transmitted over this channel so that the synchronization can occur.

ENERGY-DIFFUSION SUPPRESSION IN OSCILLATOR CHAINS

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It is known that rapidly rotating rotors are effectively weakly coupled to the neighbouring environment. This phenomenon occurs spontaneously at relatively high temperatures in different classes of systems. I discuss this problem in the context of the discrete nonlinear Schroedinger equation (DNLSE) giving evidence that it induces an exponentially suppression of energy diffusion and, thereby, leads to ergodicity breaking.
After a short introduction, where I review general properties of DNLSE, I discuss the behavior of a single breather (a rapidly rotating oscillator) superposed to a thermalized chain, to illustrate the weakness of the mutual interaction.

ATOMIC DIFFUSION ANALYSIS OF ALUMINUM-BASED COMPOSITES: AL-TI, AL-MG

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In-situ composites are a class of composites with the structure formed in the course of any processing, when the precipitation of new phases occurs spontaneously. These structures have been one of the topical areas of scientific research in recent years. Such composites have a number of properties and features that distinguish them from traditional materials, which together opens up broad prospects for use in various fields of industry.
High-pressure torsion (HPT) is an effective technique to manufacture nanostructured materials with improved mechanical properties. Recently, this method was used to obtain metal-matrix composites based on strongly dissimilar materials. For example, previously, HPT followed by annealing was successfully used to obtain Al-Cu and Al-Nb *in-situ* composites from stacked dicks.
Molecular dynamics (MD) simulation is an effective tool for studying different processes on atomistic level. In the present work, MD simulation is applied in order to study atomic diffusion behavior at the bonding interface in the Al/Ti and Al/Mg samples during compression combined with shear strain. Mechanical strength of the obtained composite is studied under uniaxial tension.
Dynamics of phase transformations in the system under consideration is investigated by MD method by the LAMMPS software package using EAM potential. These atomic structures are formed by directly combining two perfect crystals. Periodic boundary conditions apply in all directions.
Present simulation made it possible to trace on the atomistic level the mixing of Mg and Ti atoms with Al atoms from two initially separated crystals as a result of shear deformation. The proposed model is a simplification of the scenario

previously observed experimentally. Al atoms diffuse more easily into the Ti matrix than Ti atoms diffuse into the Al matrix. For Al/Mg composites, Al and Mg atoms diffuse almost simultaneously. When stretched perpendicular to the interlayer boundary of the two metals, rupture occurs precisely in the Al part of the sample for Al/Ti, and in Mg part of the sample in Mg/Ti.

SKIN EFFECTS AND BOUNDARY LAYER IN SOLID

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Boundary, surface and skin effects arising in the case of mechanical deformations and interaction with the external environment have been known for over 100 years. Despite this, the mechanics of solids practically does not take them into account in mathematical models of a rigid body. As a rule, the effect of forces on the surface is given by the boundary conditions. The concept of the boundary layer, which is necessary for the conjugation of solutions inside a continuous medium with boundary conditions, is considered only for liquids and gases. At the same time, surface effects can play a decisive role in the phenomena of plastic deformation, fatigue, and strength.
Several such effects are described in the scientific literature:
1. Influence of the surface layer on strength
2. Influence of the surface layer on plastic deformations and residual stresses
3. Influence of the surface layer on the development of hydrogen embrittlement
4. Influence of the surface layer on fatigue
5. Influence of the surface layer on acoustic elasticity
Numerous experiments carried out over the past 100 years show, for example, that the strength can change several times, and mechanical or chemical removal of a metal layer 50 μm thick is equivalent to annealing, at least in terms of the softening effect and a decreasing of residual stresses.
In the absence of a unified description using the equations of continuum mechanics, many so-called "physical models" appear, which, as a rule, explain all the effects by the formation and motion, or vice versa - by the deceleration of the motion of dislocations. Moreover, with the help of this mechanism, conflicting experimental data are explained. This approach deprives the theory of predictive capabilities and allows only a qualitative explanation of the experimental data already obtained.
The development of technologies, a decrease in standard safety margins, taking into account plastic deformations in strength calculations, the use of high-strength alloys, an increase in the corrosion resistance of structures, hydrogen energy, lead to the need to take into account various surface and skin effects in strength calculations.
One of the main drawbacks of the existing "physical models" is the lack of taking into account the purely mechanical interaction of surface layers containing a large number of dislocations with the interior of the sample. The appearance of a dislocation leads to local deformation of the material by at least half of the lattice constant of the metal, which is equivalent to huge local mechanical stresses, which significantly exceed the ultimate strength. Thus, we have a thin surface layer, which is a source of very large local stresses. Despite the small volume of this layer, it can cause significant changes in the stress-strain state of the entire metal.
Currently, there are two approaches to the continual description of the skin effect: gradient theory and description using Kasser media. But both approaches do not include an important concomitant phenomenon. When the surface layer is formed, the solid is lost, voids, micro and nanopores, microcracks, and dislocations appear. Taking into account the bulk forces and forces of surface tension at the boundaries of the formed defects, should give us a description of the phenomena of the surface effect.
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INVESTIGATION OF THE PERMEABILITY HYSTERESIS DURING SEQUENTIAL LOADING AND UNLOADING OF ROCKS

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Loading of rocks leads to their elastic and plastic deformations [1, 2], while there is a significant decrease in their permeability and an increase in the consumption of reservoir energy for the movement of fluids. Subsequent unloading of rocks in the elastic region leads to a complete restoration of permeability. Unloading rocks after plastic deformation partially restores permeability. The paper presents the experimental and theoretical results of studies of plastic and elastic deformations of rocks and the subsequent restoration of permeability. It was found that with an increase in the initial permeability of rocks, the deformation values increase [3-6]. The size and distribution of pores, fracturing of rocks, also affect the change in permeability under loading. The estimation of the values of permeability hysteresis during loading and unloading for rocks in the north of the Perm region is carried out. When processing the test results of wells developing terrigenous formations of fields in the north of the Perm Territory, the average value of the difference in permeability before loading in the plastic area and after unloading was 30%. The value of the permeability hysteresis depends on the loading period. Under short-term loading in the plastic region, the permeability can be restored completely. With an increase in the holding time of the sample under load and subsequent unloading, the difference between the initial and restored permeability increases. Hydrodynamic modeling of the development of oil deposits, taking into account the permeability hysteresis, showed that a significant decrease in reservoir pressure at the initial stages of oil production and its subsequent recovery lead to an increase in the production time of recoverable oil reserves.

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NONLINEAR WAVES IN ACOUSTIC METAMATERIALS

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The nonlinear metamaterial mass-in-mass 1D lattice model is considered. An influence of nonlinearity on propagation of elastic waves is studied on the basis of the continuum limit of the ciscrete model. An exact traveling wave solution is obtained in the form of a localized nonlinear wave. An asymptotic procedure is developed to obtain the modulation continuum nonlinear equation. The features of the wave modulation in a metamaterial is studied on the basis of the exact and asymptotic solutions to the model nonlinear equation. The differences in the modulation wave dynamics on the acoustic and optical bands are described analytically. Numerical simulations are performed to study a formation of localized waves from rather arbitrary imputs.

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DYNAMIC SLIDING CONTACT FOR A THIN ELASTIC LAYER

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The contribution is concerned with dynamics of a thin elastic layer, subject to sliding contact. Both one- and two-sided sliding contact are considered, revealing the presence of the fundamental vibration modes. First, mixed boundary conditions modelling two-sided sliding are addressed, allowing straightforward factorisation of the dispersion relation. Then, the asymmetric problem of one-sided sliding contact is tackled, with mixed conditions along the contact surface and prescribed normal stress on the opposite face. Using symmetry, this problem is found to be related to that for a layer of a double thickness, with classical boundary conditions in terms of stresses. In this case, the fundamental mode of interest coincides with the zero-order Rayleigh-Lamb symmetric wave. Long-wave low-frequency perturbation scheme is implemented for the forced problem.

EFFECTS THE ANGULAR MOMENTUM IN MATHEMATICAL MODELS OF CONTINUOUS ENVIRONMENT MECHANICS

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A model is proposed, built taking into account the influence of the angular momentum (force) in continuum mechanics. The speeds of various processes at the time of writing the equations were relatively small compared to modern ones. As a result, of the theory developed for potential flows, was wide on flows with significant gradients of physical parameters was expanded. The vector definition of pressure and the no symmetry of the stress tensor are substantiated. Result of the calculation for non-equilibrium the distribution function in flow problems by rarefied gas leads to an non symmetric stress tensor and Pascal's law is violated. It is proved that for particles without structure the symmetry condition for the stress tensor is one of the possible conditions for closing the system of equations. An example of calculation is given. . The influence of the momentum is also traced in the formation Brownian motion and Landau damping. The necessary modification of the Boltzmann equation when considering micro and macro scales is discussed.

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NON-STANDARD CONTACT CONDITIONS BETWEEN A BEAM AND A COUPLE STRESS ELASTIC HALF-PLANE

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In the present work, the problem of a deformable Euler-Bernoulli beam of length $2a$ in bilateral frictionless contact with a couple stress elastic half-plane, whose constitutive parameters are the shear modulus μ, the Poisson coefficient ν and the material characteristic length l, is investigated by assuming that both contact pressure and couple stress tractions are transmitted across the contact zone. The present study is aimed to investigate the size effects induced on the beam internal forces and moments by the contact pressure and couple stress tractions transmitted across the contact region. It may be considered an extension of the works on beams in contact with an elastic half-plane performed by Shield and Kim (1992), Lanzoni and Radi (2016), and on rigid indenters in contact with an elastic couple-stress half-plane developed by Guorgiotis and Zisis (2016) and Zisis et al. (2018).
The couple stress theory of elasticity requires boundary conditions on the microrotation and couple stress tractions in addition to the usual boundary conditions of the classic non-polar continuum on displacements and stress tractions. A challenging problem is thus how to extend the classic contact conditions to include the effects of the microrotation and couple stress tractions. In the proposed approach, the classical strain compatibility condition between the slope of the beam and that of the half-plane surface is imposed along the contact region. Moreover, three alternative kinds of microstructural contact conditions are considered and discussed, namely, vanishing of couple stress tractions, vanishing of microrotations and compatibility between microrotatons of the half-plane surface and slope of the beam. The first two types of boundary conditions are usually assumed in the technical literature on micropolar materials, although the third boundary condition seems the most correct one. Use is made of the Green's functions for point force and point couple applied at the surface of the couple stress elastic half-plane. The problem is thus reduced to one or two (singular) integral equations for the unknown distributions of contact pressure and couple stress tractions, which are expanded in series of Chebyshev orthogonal polynomials of the first kind displaying the classical square-root singularity at the beam ends. By using a collocation method, the integral equations are reduced to a linear algebraic system of equations for the

unknown coefficients of the Chebyshev series expansion adopted for the contact pressure and couple stress tractions. The contact pressure and couple stress along the contact region and the shear force and bending moment along the beam are then calculated under various loading conditions applied to the beam, varying the flexural stiffness *EI* of the beam and the characteristic length *l* of the elastic half-plane. The three alternative conditions lead to significantly different results in term of bending moment along the beam. The size effects due to the characteristic length of the half-plane and the implications of the generalized contact conditions are illustrated and discussed.
The classical elastic solution is recovered as the characteristic length becomes vanishing small. Generally, the magnitude of the couple stress tractions is found to increase with the characteristic length. Although its contribution is usually smaller than that of the contact pressure and mainly restricted to the edges of the beam, it may provide a significant influence on the shear force and bending moment along the beam. Therefore, the obtained results show that the couple stress tractions exhibit a large influence on the beam internal forces and moments and display size dependent behavior when the beam length is comparable to the intrinsic characteristic length scale of the ground.
Moreover, we show that accounting for the micropolar behavior of the ground, but neglecting the moment tractions in the contact region may lead to a substantial underestimation of the bending moment in the beam, in particular for the intermediate range of values of the material characterisic length (Fig. 1).
The most interesting applications concern the case of beam length comparable with the microstructural characteristic length, namely for the ratio of l/a equal 0.5 and 1 considered in the plots. These results are expected to be significant and useful for engineering applications, specially in the field of micromechanics. We aspire indeed that the provided results may serve as a reference for the design of structural components in contact with heterogeneous and complex materials, not only at the macroscale, but also at the micro and nanoscale, providing a fundamental basis for the assessment of the proper microstructural contact conditions.

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MATHEMATICAL MODELLING OF ICE FIELD DEFLECTION DYNAMICS

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Most hydraulic structures interacting with an ice field have inclined faces. Depending on the angle of inclination at the point of their contact, a force occurs leading to bending and subsequent destruction of the ice field. Estimating the maximum stresses that occur during the deflection of the ice field remains an important task.
A standard calculation of the stresses on an ice field usually involves the model of a beam (plate) on an elastic hydraulic foundation [1]. Many authors have considered the static formulation of the problem [1], [2] , etc. However, according to the experiments, the absolute value of the deflection of an ice field under static loads is less than under the dynamic loads.
The problem of finding the analytical solution to the dynamic problem of deflection of a beam on an elastic foundation with boundary conditions of the first and second kinds is considered nontrivial. Nowadays, the methods for obtaining such a solution for these boundary conditions using the apparatus of mathematical physics are not fully developed. Thus, it is necessary to solve this problem numerically, using various computing resources. Several attempts had been previously made to obtain the analytical solution with a similar problem statement [3], but it involves a large number of parameters of the physical environment, which makes it difficult to use.
The purpose of this paper is to obtain the analytical solution to the equation of dynamic deflection of an ice field, taking into account an elastic foundation for two formulations – one-dimensional (beam bending model) and two-dimensional (plate bending model).
To integrate a linear homogeneous differential equation of the fourth order in partial derivatives, we used the apparatus of integral transformations, as well as the theory of the function of a complex variable. The deflection function obtained as a solution allows to obtain stresses analytically at each point of an ice field. Undoubtedly, this is an advantage compared to the numerical methods which involve separate calculation scheme to determine the stresses.
In order to verify the validity of the obtained solution, a number of the experiments on the interaction of an ice field and

an inclined structure have been carried out in the Krylov State Research Center. According to the graphs of the force measured experimentally with the use of linear function interpolation, the proportionality coefficients have been found, which are then used in the boundary conditions of the analytical solution. As a result, the time and location of the breaking point, determined by comparing the maximum stresses in the beam and the ultimate strength of the ice, coincided with the experimental data. The measure of inaccuracy was 3%. The dynamic setting has showed the most accurate deflection values compared to the static setting.

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EXPERIMENTAL STUDIES OF THE MECHANICAL CHARACTERISTICS OF ROCKS UNDER DYNAMIC LOADING

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The change in the geomechanical characteristics of rocks under the influence of dynamic loads on them is an important phenomenon that should be taken into account when geotechnical engineering. Knowledge about the nature of the change in the mechanical characteristics of the rock (Young's modulus, Poisson's ratio, compressive strength, etc.) under dynamic loads is necessary, for example, in the construction of wells. Under the influence of dynamic loads, the mechanical strength of rocks can either increase or decrease, depending on the magnitude and frequency of loading. Among the existing experimental works, the most common is the study of the mechanical characteristics of rocks on standard equipment (loading stands) in the field of seismic prospecting (with relative rock strain up to 10E-4). The dispersion of mechanical characteristics in such works is justified by the presence of liquid in the investigated rock samples [1]. Similar experimental work carried out with dry rock samples does not demonstrate similar results [2]. Recently, the authors of [3] have created a setup that allows to measure the dynamic elastic characteristics of rocks at a frequency of impact up to 1 kHz and strain up to 10E-5. However, taking into account that during geotechnical engineering (for example, construction and perforation of wells [4]) rocks experience higher strain (more than 10E-2), it is necessary to expand the capabilities of the installations. It is possible to study the effect of significant dynamic loads during rock strain from 10 to 10E4 using the Hopkinson-Kolsky setup, but the setup does not allow creating cyclic (harmonic) loads. Therefore, laboratory studies of geomechanical characteristics require the creation of experimental installations for dynamic loading. According to the results of studies on experimental installations for dynamic loading of dry samples, carried out in a narrow frequency range (from 10 Hz to 40 Hz) with a relative strain of the rock up to 10E-2, there is a dispersion of the dynamic component of Young's modulus [5]. Thus, the study of the mechanical characteristics of rocks in the field of high-amplitude nonlinear loading requires further laboratory experiments on specialized equipment.

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HEAT TRANSFER IN INFINITE ONE-DIMENSIONAL CRYSTAL CONSIDERING THE N-TH COORDINATION SPHERE

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An influence of interactions with non-nearest neighbours in a one-dimensional harmonic crystal on the process of heat propagation is studied. Two different models were considered. One is a crystal with interactions up to the third coordination sphere which is an incremental advance of the latest studies in the field. The influence of the variation of stiffnesses between the particles of different coordination sphere is a subject of the studies. The second model focuses on expansion of the number of interactions considered taking into the account fixed type of forces present between the particles. Previously developed model of the ballistic nature of the heat transfer is used. The fundamental solution of the heat propagation problem was constructed. It is shown that the initial thermal perturbation evolves into several consecutive thermal wave fronts propagating with finite velocities. The number of fronts coincide with the number of coordination sphere considered. In the case of the third coordination sphere the velocities of fronts are different and correspond to group-velocity extrema. Second and third front arise at a certain ratio between stiffnesses. For the variative coordination sphere with the decreasing dependency of the stiffnesses on the number of interacting neighbours the front velocities coincide and increase with the raise of the number of interactions considered. The analysis of the second model is provided with the description of the asymptotic behaviour of the system corresponding to the crystal with the infinite coordination sphere.

DYNAMICS OF AUTOWAVES UNDER THE INFLUENCE OF NOISE IN A SYSTEM OF COUPLED MAP-BASED NEURON MODELS

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The objective of this work is to study numerically the dynamics of a two-dimensional lattice of locally coupled Rulkov maps. We analyze the conditions for the appearance and existence as well as the properties of autowave spatio-temporal structures which are represented by spiral and target waves. The influence of noise on the lattice dynamics is explored as the noise intensity and the size of the noise-disturbed region are varied. We have used numerical experiments for the investigation of the evolution of the lattice dynamics is directly determined by the corresponding recurrence relations. The numerical data are used to construct spatial distributions of the instantaneous values of the amplitudes for all the network elements, spatio-temporal diagrams for the lattice cross-section at different values of the control parameters of the individual nodes, for various noise intensities and different sizes of the noise-disturbed region. The noise-disturbed region is specified as a square which consists of a small number of oscillators at the lattice center. It is found that for certain values of the control parameters of the maps, of the coupling parameters, and the initial conditions, long-lived spiral and target waves can exist in the lattice. It is shown that the spiral wave regimes are, as a rule, transient, can be observed for a finite time and become long-lived only for certain values of the parameters and the initial conditions. When the noise influences a finite region of the lattice showing spiral waves, the transition to spiral waves with a different structure or to target waves can occur. However, if the noise disturbance is removed, the lattice returns to its original mode or exhibits the transition to coherent dynamics modes. The target waves are more resistant to the noise and are observed for longer times. If the noise causes the target waves to change, the resulting regime continues to exist after removing the noise source. The regions where these waves exist are defined and constructed in the plane of the control parameters of the individual elements. Studying the impact of the relation between the noise intensity and the size of the noise-disturbed region enables one to distinguish the region where the transition from spiral to target waves always occurs, as well as the area inside which this transition depends on the initial states of the lattice elements and the noise realization.
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EFFECT OF THERMAL WALL BOUNDARY CONDITIONS ON A VISCOUS FLUID FLOW THROUGH AN ABRUPT CONTRACTION

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Abrupt changes in a geometrical configuration of pipeline systems are typical for a number of industrial applications. In particular, sudden contractions encounter in chemical reactors, heat exchangers, extruding machines, etc. For these and other engineering equipment, it is extremely important that, in the course of technological processes, the liquid medium transportation is carried out in a given regime with known energy losses under certain thermal conditions.
This study is devoted to a non-isothermal viscous fluid flow through an axisymmetric sudden contraction with account for viscous dissipation effects and a dependence of the fluid viscosity on temperature. A particular feature of the problem is a mixed type of thermal boundary conditions assigned on a solid wall, namely, a constant heat flux is prescribed in the contraction vicinity, while the rest part of the wall is characterized by a constant temperature value. Mathematical formulation of the problem includes momentum, continuity, and energy equations, which are written in terms of stream function, vorticity, and temperature. The finite-difference method based on the alternative directions scheme is employed to discretize governing equations. A resulting system of algebraic equations is solved using the tridiagonal matrix algorithm.
The calculated results are presented as velocity, temperature, and viscosity fields, and are analyzed depending on the pipe contraction ratio and dimensionless criteria. Distribution of the Nusselt number along the solid wall is shown as a function of the Reynolds, Peclet, and Brinkman numbers. A parametric study is performed to reveal the impact of thermal wall boundary conditions on the flow structure and local energy losses.
This work is implemented at the expenses of the Russian Science Foundation (project No. 18-19-00021-П).

INFLUENCE OF DENTAL TREATMENTS ON MINERAL DENSITY OF WHITE SPOT LESIONS USING X-RAY MICROTOMOGRAPHY: EX VIVO INVESTIGATION

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The initial stage of caries is characterized by demineralization of the enamel (both in the coronal and cervical parts) without cavitation. Such a pathology is called the white spot lesion. Often in the clinical practice dentine in the vicinity of demineralized enamel may also be involved in the process. Dental clinicians use a variety of techniques to treat this type of caries. *Ex vivo* laboratory testing techniques are used to assess the effectiveness of treatment methods. In the present work, we propose an approach to assessing the effect of various methods of treating white spot lesions on the mineral density of enamel and dentine using X-ray computed microtomography (micro-CT), as well as a protocol for processing three-dimensional tomography of the tooth before and after treatment in VGSTUDIO MAX 3.4 (Volume Graphics, Germany) software environment.
We used human molars extracted for orthodontic purposes from patients at the clinic of the Rostov State Medical University (Rostov-on-Don, Russia) as samples. The Independent Ethics Committee of Rostov State Medical University approved the study, the patient provided informed consent. Imaging of the samples before and after treatment was performed using an Xradia Versa 520 device (Carl Zeiss X-ray Microscopy, Inc., USA). Treatment of areas of white spot lesions was carried out by a dental clinician with three materials: infiltrant (minimally invasive treatment technique), glass ionomer cement and composite according to the protocols recommended by the manufacturers.
To correlate the geometry of the caries area before and after treatment, a following protocol was established:

- determination of the surface of the entire tooth with calibration phantoms;
- conversion of the surface to the region of interest, determination of the surface from the obtained region of interest;
- combining three-dimensional models before and after treatment, registering one three-dimensional model relative to another to correlate their spatial coordinates;
- study of mineral density by regions using virtual volumetric cylinders containing tooth tissue material.

The main goal of the study was to help evaluate the efficacy of modern approaches to caries treatment and thereby to help the dental clinician to choose the most optimal strategy for treating patients.
The study was supported by the Government of the Russian Federation (grant 14.Z50.31.0046).
Microtomography was carried out at the Nanocenter of Don State Technical University (https://nano.donstu.ru).

STUDY OF THE MECHANICAL PROPERTIES OF GRAPHENE-NICKEL COMPOSITE BY MOLECULAR DYNAMICS

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The study of the interaction of carbon materials with metal nanoparticles has recently become a rapidly developing field, revealing exciting properties, which offers a variety of applications in electronics, for creating new generation composites, in energy, biomedicine, for developing a new generation of supercapacitors, etc. In this work, the effect of the size of nickel nanoparticles and processing temperature on the mechanical properties of the graphene-nickel composite was studied by the molecular dynamics method.

To create new-generation composites, the structure of crumpled graphene is considered as a matrix, and nickel nanoparticles of several sizes, consisting of 21, 47, and 78 atoms, are considered as a matrix filler. This combination can improve physical properties of the components which allow to obtain structure with much greater functionality. To form a composite material, hydrostatic compression is applied to the initial rather porous structure at various temperatures. Other way for obtaining a composite are also considered, for example, the use of hydrostatic compression followed by annealing at different temperatures and annealing followed by compression at different temperatures. The mechanical properties of the composite are evaluated using hydrostatic and uniaxial tension along the x, y, and z-axes.

As a result, it was revealed that one of the important factors in obtaining a composite is the size of nickel nanoparticles. Structures with Ni_{21} and Ni_{47} nanoparticles have the best characteristics, since with this size of nanoparticle it does not fill graphene flake totally, and allow the structure to deform freely. The appearance of new chemical bonds that are responsible for the strength properties of the material will appear during high temperature treatement. It was found that the best way to obtain a graphene-nickel composite is annealing followed by compression at elevated temperatures in the range from 1000 to 2000 K.

DYNAMIC PROBLEMS FOR A PERTURBED ELASTIC RECTANGLE SUBJECT TO END LOADINGS

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In this work, low-frequency perturbations to rigid body dynamics of an elastic rectangle subject to end loadings are formulated. The derivation is presented for both anti-plane and plane motions of the rectangle. The proposed perturbation procedure based on a small parameter related to the low-frequency results in non-homogeneous boundary value problems for harmonic and bi-harmonic equations corresponding to leading and next order expansions, respectively. The solution corresponding to anti-plane translation is expressed by Fourier series. The analysis of the plane translation is given for an elongated rectangle which may be also analyzed by using the elementary theory of plate extension. The obtained asymptotic formulations allow calculating the variation of stresses and displacements over the interior of the rectangle, including the case of self-equilibrated loading, which cannot be treated within the classical rigid body model. The numerical comparisons of exact and derived asymptotic formulae are presented to show the accuracy of the perturbation scheme.

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ANALYTICAL AND NUMERICAL SOLUTIONS OF THE MODIFIED SYSTEM OF INTERRELATED KINETIC EQUATIONS FOR CREEP AND LONG-TERM STRENGTH OF METALS

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The problem of creep and long-term strength of metallic materials and alloys is considered. Under the long action of relatively small stresses and high temperatures many metallic materials lose plasticity and fractured as brittle with a small value of residual deformation. This problem is known as the problem of thermal brittleness of metals. These effects are observed in elements of many important engineering objects, in particular, in power and nuclear, so the problem of brittle fractures became a subject of numerous theoretical and experimental investigations.
To solve this problem a system of kinetic equations for the damage parameter and creep deformation was considered in the works of L.M. Kachanov [1], Yu.N. Rabotnov [2]. A modified version of the Kachanov-Rabotnov system of kinetic equations was proposed in the work of R.A. Arutyunyan [3]. In which the mass conservation law is taking into account and the damage parameter is specified in the form of a relative changes of the material density. There are numerous experimental studies on changes of the porosity and density of various metals and alloys due to the formation and development of micropores and microcracks in the conditions of high-temperature creep. These results allow considering the density as an integral measure of the accumulation of structural micro-defects, and defined the damage parameter as the ratio of current density to initial.
An exact analytical solution of the proposed system of kinetic equations is not possible. In this regard, various cases of approximate solutions of this system were considered [4]. Approximate analytical solutions of the system of equations are obtained and criteria for long-term strength are formulated, which make it possible to describe the area of brittle fracture. The corresponding theoretical curves are plotted. It is shown, that the proposed system of kinetic equations is capable of describe the third section of the creep curves, and the Kachanov-Rabotnov long-term strength criterion is a particular case of the obtained criterion. It is also shown that the creep deformation according to Rabotnov's theory is accumulated more intensively compared with the solution of the proposed system. Also, an exact solution of the modified system of kinetic equations was obtained in the form then the damage parameter as a function of the deformation value.
An exact solution of the proposed system of kinetic equations is obtained as functions of time using numerical methods. Comparison of approximate and exact solutions is given. It is shown, that the nature of theoretical creep and damage parameter curves according to different solutions is identical and agrees with the corresponding experimental results.

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MOMENT-MEMBRANE DYNAMIC THEORY OF ELASTIC THIN SHELLS AND VARIATION PRINCIPLES

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Paper [1] demonstrates the construction of the moment-membrane static theory of elastic thin shells (as a particular case, of thin plates under bending and plane stress), which otherwise is called the model of thin shells based on the moment theory of elasticity with independent fields of displacements and rotation with the concept of deformation shear plus rotation. This model can be applied as a continuum model to study the deformations of nanomaterials. In particular, paper [1] proves the energy theories for the moment membrane static theory of shells and establishes the variation principles of Lagrange and Castilliano type.
The present paper generalizes the approach developed in [1], further it demonstrates the development of the moment-membrane dynamic theory of elastic thin shells, for which the principle of virtual work is established. Also, the main energy equation, the law of conservation of energy, is established, which can be applied to prove the uniqueness of the theory for the initial boundary-value problems of the constructed theory. The paper considers a particular case, when the causes of the shell's deformation and the motion undergo harmonic changes in a time (at the same time, a) the amplitudes of displacements and free rotations are subject to variation; b) the amplitudes of internal moments and forces

are subject to variations); the extreme properties of the corresponding functionals are proved. Further, the variation principle of Hamilton type is established for the moment-membrane dynamic theory of elastic thin shells, based on which equations of motions and the corresponding boundary conditions of the theory are derived.

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NUMERICAL ASPECTS OF THE J-INTEGRAL ESTIMATION FOR THERMAL LOADING

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Pipelines are an important part of a lot of constructions extensively used for oil and gas industry applications. Modeling of crack behavior and determination of their characteristics can prevent some emergency cases and reduce maintenance and operation costs.
In the study we have investigated the crack behavior under thermal loading for classical fracture mechanic's problem – edge cracked strip subjected to thermal loading (Wilson, 1979) [1]. Different types of temperature distribution were analyzed (a linear temperature gradient through the thickness with zero temperature at mid-thickness and temperature T_0 at the right edge and a constant temperature distribution).
The numerical simulations of these problems were performed using ANSYS [2] and PANTOCRATOR [3] software. The fact that the J-integral is independent of the path around a crack was shown. The contour selection recommendations were made based on detailed analysis. The influence of the number of elements on the value of the J-integral was presented. J-integrals for each problem statement were evaluated. Linear and quadratic finite elements of triangular and square shapes were used.
The impact of various numerical aspects was estimated and recommendations for further work were made.
Moreover, obtained results can be enlarged in relation to the different types of thermal loading, values of crack opening and different cases of their interaction.

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RAPID COMPRESSION MACHINE STUDIES ON THE SYNTHESIS OF UNSATURATED HYDROCARBONS AND HYDROGEN FROM NATURAL GAS

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Natural gas (NG) has, so far, been used as a resource for providing mechanical energy, via its application as a fuel in combustion engines. The route of energy conversion is, therefore, from chemical energy via thermal energy to mechanical energy (work, electricity), representing the paradigm of energy conversion that has prevailed in technological applications during the last decades.
In our paper, we propose and investigate an alternative form of energy transformation, namely from mechanical to chemical: Using mechanical energy in the form of compression work, chemical reactions in natural gas can be stimulated, leading to formation of high-value chemicals, notably, unsaturated hydrocarbons and hydrogen. Prospective uses of such a process lie, on the one hand, in the production of high-grade chemicals from the cheap resource natural gas, and, on the other hand, also in the high enthalpy of formation of the products (like C_2H_2, C_2H_4, H_2) relative to NG. Additional positive prospects arise from the fact the required input of mechanical energy can be provided inexpensively, e.g. from local or temporal surpluses from wind or solar energy.
To study the feasibility of this chemical conversion, we conduct experiments in a rapid compression machine (RCM), which is a piston-cylinder type compressor that can be used to mimick the processes in a piston engine.
In the RCM experiments, natural gas is compressed to high temperature and pressure under well-defined initial and boundary conditions, allowing chemical reactions to set in. By sampling the post-compression gas from the reaction

chamber and performing gas chromatographic analysis, we can monitor the achieved extent of chemical conversion, and the nature and amounts of produced substances (species yields).
A series of such experiments is performed to study how the experimental conditions affect the conversion of methane and the yields of products. Results show that conversion at engine-typical compression ratios and initial conditions (temperature, pressure) is possible, if the natural gas is diluted with low heat capacity gas (e.g. noble gas Argon). At post-compression temperatures of about 1500 K, significant conversion sets in. The spectrum of produced substances depended on the temperature range: Higher compression temperatures tend to yield more C_2H_2 and H_2, lower temperatures lead mainly to C_2H_4 and C_6H_6.
With respect to the conversion into chemical energy, the experimental data show that the difference of standard energy of formation between products and initial substance (NG surrogate methane) can be in the range of 10 MJ per kg of methane. This high value encourages the use of the conversion also for high energy density energy storage.

ON SOME EFFECTS OF DIFFERENT TEMPERATURES ON THE LIFETIME OF THICK-WALLED VESSELS UNDER MECHANOCHEMICAL CORROSION CONDITIONS

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Corrosion is natural deterioration of materials due to their interaction with environment. The rate of corrosion may be enhanced by increasing temperature, however, sometimes the latter may decrease the corrosion rate due to faster formation of protective layers. One of the other ways how temperature may affect the corrosion rate is mechanical activation of corrosion by thermal stresses caused by non-uniform heating. This paper is devoted to the study of the mentioned effects of different temperatures of the internal and external environments on the lifetime of the vessels under the conditions of mechanochemical corrosion. The rates of corrosion on the inside and outside are assumed to be linearly dependent on the circumferential stress on the related surface, as well as on their temperatures, with possible inhibition of corrosion taken into account. Benchmark analytical solutions are presented. In the presence of internal or external pressures, the elastic – not the thermal – stress component plays a decisive role in the synergistic growth of mechanical stress and the corrosion rate. In this case, one of the stress fracture criteria should be used for the assessment of the lifetime of the vessel. In the cases when the pressures of the internal and external media are absent or equal one to another (for equal or unequal temperatures), the solutions should be adapted to the criterion of a minimal residual thickness. The lifetime of the vessels is determined by the competition of different mechanisms discussed in the paper.
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ACCOUNTING FOR THE SKIN EFFECT IN HYDROGEN-CHARGED SAMPLES IN THE HEDE MODEL OF CRACKING

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As known, hydrogen embrittlement and hydrogen-induced destruction are one of the serious problems of modern engineering practice. Nowadays, several approaches have been proposed to describe this phenomenon. One of the most widespread and most developed is the hydrogen enhanced decohesion model (HEDE). Its mechanism presupposes fundamentally brittle fracture as a result of hydrogen embrittlement without plastic deformation.
In all currently existing studies of the HEDE model, the hydrogen content throughout the sample is considered uniform. At the same time, it was experimentally established that the procedure for charging specimen with hydrogen leads to a highly uneven distribution of the concentration of this substance over its volume. In a surface layer with a thickness of the order of one material grain size, its value can be tens of times greater than the value inside the sample. This phenomenon is called skin effect, and so far, modeling of hydrogen destruction has been carried out without taking this fact into account.
In this work, we focused on the application of the HEDE model of brittle fracture taking into account the skin effect from charging the samples with hydrogen. We performed finite element simulation of the fracture of a hydrogen-charged steel cylindrical corset specimen with a notch, setting the specimen parameters and loading conditions to be typical for hydrogen brittleness experiments. According to the results, it was found that the unevenness of the distribution of hydrogen concentration can be the main source of the dual nature of sample fracture - brittle induced by hydrogen on the surface of the sample and common inside its volume.
The research was supported by the Russian Foundation for Basic Research (project No. 20-08-01100).

NONUNIFORM DEPLOYMENT OF MOBILE AGENTS OVER THE SEGMENT OF THE CURVE

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In the paper the problem of nonuniform deployment of a group of mobile agents over a segment of a smooth curve is studied. An asymptotically stable decentralized algorithm that provides a solution to the problem is proposed. It is shown that neither delays in information transfer between agents, nor changes in the network configuration (switches) affect the achievement of the goal using the proposed algorithm.
The asymptotic stability of the algorithm is proven for the following cases:without disturbances; with delays in information transmission; with changes of network configuration - switches; as well as the case when there are both delays and switches. The resulting theory may be useful in practical applications and for further development of the theory of multi-agent control systems. In particular, one can design an algorithm for equidistant placement on an arbitrary smooth curve, and the distance can be understood in di erent ways, either in the Euclidean sense or, for example, in the geodesic sense. The stability to lags and switching makes the proposed control algorithm suitable for direct use in engineering problems, e.g. in traffic control problem.

CHALLENGES AND OPPORTUNITIES OF ADDITIVE MANUFACTURING: MICROMECHANICAL ANALYSIS

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Metal Additive Manufacturing (AM) technologies are still at its early stage of development, and the fundamental processing-microstructure-property relationships are not fully understood. Without optimized processing parameters, defects can often occur in parts produced with AM. The key parameter that governs overall material properties of AM materials is their microstructure. Laser scan strategy (particularly scan speed) noticeably affects the microstructure and the quality of the produced specimens. Generally, AM materials have a complex microstructure with anisotropic orientation of individual grans and porous space formed by pores and cracks of diverse shapes. The problem arises regarding the proper quantitative characterization of such a complex microstructure. We discuss a background for modeling of such materials consisting of the following specific research problems. First, the microstructural features that produce major and minor effects on the overall mechanical, thermal, and electric properties of AM materials are identified. The basic requirement for proper microstructural parameters is that it must represent individual defects according to their actual contributions to the considered property. Violation of this basic requirement may lead to inconsistencies. We established (at least at qualitative level) the correlation between processing parameters of the deposition and microstructural features of major importance for elastic and electric properties. It allows development of a model for the microstructure of the AM materials dependent on processing parameters, and identify those parameters. This model, in turn, leads to new methodology of the in-situ and ex-situ quality control of metal based AM parts using methods of micromechanics. The presentation will also identify the most important open problems and discuss potential ways to address them.

NUMERICAL MODELING OF FRACTURES WITH A BEND IN SPACE

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Strength of Space vehicles is a crucial issue for Space flight safety. The presence of latent defects in the material has a significant effect on the strength at different loads: the speed and direction of crack growth.
All celestial bodies have defects in the form of cracks. Some of the bodies are large. Colliding with such objects can be dangerous. Therefore, the problem of grinding such bodies remains very urgent. In order to avoid large financial costs, you need to know where to strike in order to achieve the greatest effect.
A method of boundary elements called the method of discontinuous displacements, was chosen as the numerical method. The code is implemented in C++.The advantage of this method is that only the crack boundary is divided into elements, which allows the use of a small (compared to other numerical methods) amount of computer memory. Calculating the singular integral is required when solving problems involving one crack. In case of several cracks, such integrals are not analytically incalculable. In this study, we present a method that does not require the calculation of singular integrals. In this paper, we study a three-dimensional elastic medium weakened by a system of plane cracks and

one crack with a bend. A comparison was made with known analytical results. Bend crack behavior is studied for various loads.

CREATION OF SURROGATE MODEL FOR PREDICTION THE EFFECTIVENESS OF CHEMICAL ENHANCED OIL RECOVERY METHODS: GENERATION OF THE TRAINING SET WITH THE AID OF TNAVIGATOR HYDRODYNAMIC SIMULATOR

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Chemical enhanced oil recovery (EOR) methods play an important role in the exploitation of mature oil fields. The effectiveness of such methods depends on a combination of a large number (up to 52 in the present work) of different factors. Therefore, computer hydrodynamic simulation of oil reservoirs can help to predict the effectiveness of different enhanced oil recovery methods, including chemical methods.
Hydrodynamic simulator tNavigator [1] is widely using in the oil industry. But it usual situation when the calculation time, even with the use of a supercomputer, can reach several days (up to a week). This makes it very difficult to predict the efficiency of chemical EOR, especially when it is needed to calculate a number of ranges for 52 parameters. This problem can be overcome by developing a surrogate model with the aid of machine learning. Calculations using such a model should not exceed a few minutes.
Present work is devoted to the development of software for the automatic generation of training set cases using tNavigator as a hydrodynamic simulator.

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INTER-LAYER SYNCHRONIZATION OF WAVES IN MULTIPLEX NETWORK OF COUPLED SELF-OSCILLATORS

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We present numerical results for the synchronization phenomena in a bilayer network of repulsively coupled 2D lattices of van der Pol oscillators. We consider the cases when the network layers have either different or the same types of intra-layer coupling topology. When the layers are uncoupled, the lattice of van der Pol oscillators with repulsive interaction typically demonstrates a labyrinth-like pattern, while the lattice with attractively coupled van der Pol oscillators shows a regular spiral wave structure. We reveal for the first time that repulsive inter-layer coupling leads to anti-phase synchronization of spatiotemporal structures for all considered combinations of intra-layer coupling. As a synchronization measure, we use the correlation coefficient between the symmetrical pairs of network nodes, which is always close to -1 in the case of anti-phase synchronization. We also study how the form of synchronous structures depends on the intra-layer coupling strengths when the repulsive inter-layer coupling is varied.

FEATURES OF SHOCK WAVES INDUCED IN A PHOSPHORENE NANORIBBON

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We perform a detailed analysis of the quantitative structural parameters and energy dissipation channels in a hexagonal phosphorene nanoribbon subjected to shock loading. This external influence leads to the excitation of a shock wave in the material. We found that to excite shock waves, it is sufficient to apply a directed initial pulse per atomic row in the direction normal to this row. At the same time, these initial conditions do not correspond to the stable profile of the shock wave, and it is formed after a sufficiently short transition period of 0.1 - 0.2 ps. We show that the shock waves in phosphorene can propagate only in two crystallographic directions, namely in zigzag or armchair. In all cases, shock waves propagate faster than the speed of sound with a sufficiently large energy dissipation. The mechanisms of shock wave propagation and energy dissipation channels are also investigated in detail.

COLD SPRAY DEPOSITION OF COMPOSITE CU-W COATINGS

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Tungsten is one of the heaviest, hardest and most refractory metals. Alloys based on it are distinguished by high hardness, heat-, acid- and wear resistance, and the high density of tungsten makes its alloys an indispensable material for protection against ionizing radiation. Tungsten and the substances that make up its alloys (copper, nickel, iron) have significantly different physical properties, primarily the melting point. It is impossible to produce an alloy of them in the usual sense, because at the melting point of tungsten, most metals are in the state of gases or volatile liquids, therefore the so-called pseudoalloys are produced only by powder metallurgy methods. To produce copper-tungsten coatings with high thermal and electrical conductivity at elevated temperatures, gas-thermal methods are currently used, in particular, plasma spraying and HVOF spraying. In turn, the cold spray method has great potential for creating tungsten-based coatings with low porosity, uniform distribution of components and absence of oxidation. The present work is devoted to an experimental study of the effect of tungsten content in the copper matrix of a cold sprayed coating on its mechanical properties (microhardness, elastic modulus, adhesion strength).

MICROPOLAR THEORY WITH NON-LOCAL POTENTIAL INTERACTIONS

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A micropolar theory of continuous elastic media with nonlocal potential interactions of its infinitesimal particles is proposed. The interaction potentials depend not only on the mutual position, but also on the mutual orientation of the particles. A local model is constructed on the basis of a non-local model. The representation of small increments of kinematic characteristics by polynomials of the first and second degree with respect to their change allowed us to obtain it. The well-known linear model of micropolar elastic materials is a special case.
The method for calculating the material characteristics of micropolar materials is presented in the report. Information about the characteristics of the interaction potentials between particles is its basis.
The need for a quantitative description in the framework of deformable solid mechanics of the relationship between the polarization of materials and the mutual transformation of the rotational and translational energy of particle motion motivates this work.
The real material considered in continuum mechanics has a complex structure of the arrangement, orientation, and interaction of its elementary particles. They may change over time. The effect of this on the continuous medium properties is taken into account in [1]. It presents a new aspect of the generalized continuum theory, namely, micropolar media showing structural changes.
In the framework of solid state mechanics, the simulation of the influence of non-local potential interactions of elementary particles of a real material is presented in the report. Continuum particles are considered dipoles. Their dipole moment is the average of the dipole moments of real particles. At finite distances occurs the interaction. It is described by the translational [2] and orientation potentials of pair interactions. The orientation potential is similar to the Stockmeier potential. The external electric field has an orienting (polarizing) effect on the dipoles. The first potential depends on the distances between the particles. The second potential depends on the relative distances, the relative orientations of the particles, and their orientation vector of their relative position.
An example of calculating the values of the elastic constants of the micropolar media of the local model for polarized silicon is given.
The model considered in the report can complement the work [1] in quantifying the material constants of micropolar media and the degree of anisotropy induced in them by polarization.

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ON THE INFLUENCE OF INHOMOGENEITY ON A NONLINEAR ELASTIC CYLINDER WITH INTERNAL STRESSES UNDER TORSION

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Technological advances entail the emergence of new construction materials, the properties of which are superior to the traditional ones: specific mechanical properties (strength, elasticity) are increased; resistance to the influence of the utilized environment (temperature, aggressive and corrosive environment, various types of radiation); durability and reliability during operation. Among them are distinguished those that have continuous media with an inhomogeneous structure depth - Functionally Graded materials.

Functionally Graded materials are representative of such continuum that have found their application in information, transport, aerospace, and medical technology, thermal and electric power industry, and automotive industry.

To analyze the influence of the inhomogeneity of the material elastic properties, the stress-strain state of a twisted nonlinear elastic hollow cylinder with an additional field of internal stresses was studied. Its source is an isolated defect - wedge disclination. The inhomogeneity was modeled by a linear and nonlinear functional dependence for the cylinder`s wall thickness of one of their elastic module, which corresponds to the shear modulus for infinitesimal deformations.

To describe the nonlinear elastic properties, the well-known models of the homogeneous, isotropic, compressible type were used: the model of the simplified and hypothetical Blatz-Ko material, and the semi-linear material (John material).

The three-dimensional problem of torsion of a hollow cylinder using the Saint-Venant's method was reduced to a boundary value problem for an ordinary second-order differential equation with respect to the radius function of the cylinder points with loadfree lateral surfaces.

Solution analysis of this problem has showen the presence of a second-order effect: the direct and inverse Poynting effect at different ratios of the modulus values on the inner and outer lateral surfaces of the cylinder. The disclination parameter had a significant effect not only on changing length of the cylinder (shortening or elongation), but also on the deformation value.

NONLINEAR MECHANICS OF FRAGMENTED BEAMS

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Fragmented structures are blocky structures assembled from separate units without any binding material or connectors. The structural integrity of these structures is provided by the topology of assembly, shapes of its fragments and peripheral constraints. Fragmented structures are characterized by unique mechanical behaviour and enhanced mechanical properties, such as elevated energy absorption, excellent fracture toughness, reduced thermal stresses, and more. In the case of fragmented beams, the constraints are applied at the edge blocks in the form of external axial forces or predefined displacements, which in turn generates axial compression along the whole beam. Though this axial compression provides the beam with a mechanism for the shear and bending resistance, it also introduces a destabilizing factor in the form of P-Delta effect and leads to the global loss of stability. Due to the absence of binding, the bending behaviour of the fragmented beam depends on the state of the interface between the blocks, which is mainly controlled by the level of the initial compression (prestress).

In this study, we investigate the bending and buckling resistance of fragmented beams through the analytical modelling of the interfaces between the blocks. We observe that the progressive detachment between the fragments leads to the evolution of stresses at the contact areas. These detachments and stress concentrations impair the bending stiffness of the beam, and together with the axial compression, present a destructive coupled mechanism. We analyse this dual role of the compression load in the nonlinear response of fragmented beams and demonstrate that the localisation of the detachments and P-Delta effects are critical for the assessment of mechanical performance of fragmented beams.

STABILITY ANALYSIS OF NANOSCALE SURFACE PATTERNS IN ULTRATHIN FILM COATING

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Experimental studies have shown that roughness can be formed on free surfaces and interphases of film coatings at the stage of fabrication. During exploitation, these defects evolve resulting in a deterioration in the quality of devices created on their basis. Therefore, investigation of the processes leading to the growth of surface and interfacial defects in film coatings is an important technological problem. It should be noted that in most of the theoretical works which have been aimed to understand the surface pattern formation in solids, the surface elasticity effect was neglected since it was believed to be relatively small in comparison with the bulk elastic behavior. However, numerous experimental and theoretical results demonstrate that the impact of surface stress becomes important in the mechanics and thermodynamics of nanostructured materials.
In the present study, we propose a theoretical approach to the analysis of the surface morphological stability of the film coating. The impact of the surface/interface elastic properties is taken into account based on the Gurtin – Murdoch surface/interface elasticity model [1]. We assume that the surface evolution of the film coating occurs due to surface diffusion driven by a nonuniform distribution of the chemical potential along the undulated surface. It is expected that the nonuniform distribution of the chemical potential along the surface is caused by changes in the stress field, surface energy, and surface curvature. We consider the evolution of the surface relief as a change in the amplitude of the periodic undulation. To derive the evolution equation, it is necessary to find the stress-strain state of the system under consideration. For this purpose, we formulate the plane elasticity problem for the thin film coating with undulated surface profile considering the relief evolution as a quasi-static process. The solution of the corresponding boundary value problem is derived using the approach proposed in [2]. After that, the governing equation is obtained that gives the amplitude change of surface undulation with time. Its analysis allows to explore the effect of the physical and geometric parameters on the morphological stability of film surface.
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STABILITY ANALYSIS OF APSIDAL ALIGNMENT IN DOUBLE AVERAGED RESTRICTED ELLIPTIC THREE BODY PROBLEM

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We are dealing with the averaged model used to study the secular effects in the motion of a body of the negligible mass in the context of a spatial restricted elliptic three-body problem. It admits a two-parameter family of equilibria (stationary solutions) corresponding to the motion of the third body in the plane of primaries' motion, so that the apse line of the orbit of this body is aligned with the apse lines of the primaries' orbits. The aim of our investigation is to analyze the stability of these equilibria. We start by proving their stability in the linear approximation. Then Arnold-Moser stability theorem is applied to obtain the sufficient conditions under which the stability in a nonlinear sense takes place. As it turned out, these conditions are satisfied for all parameters of the problem, with the exception of parameters from some finite set of analytic curves in space of parameters. These exceptional values of parameters correspond to resonances 1:1 and 2:1 between frequencies of oscillations of the apse line in the plane of primaries' motion and across this plane and to a degeneration of 4th order Birkhoff normal form of the problem's Hamiltonian. We have shown that in the case of 2:1 resonance apsidal alignment is unstable. In other cases, the violation of the conditions of Arnold-Moser theorem does not lead to instability.
Our results hopefully will be useful for studying the dynamics of exoplanetary systems Many exoplanets move in orbits with large eccentricities and inclinations. Therefore, an understanding of possible mechanisms of instability of planar orbits is important in this context.
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MODELING THE DISPLACEMENT OF OIL FROM A POROUS MEDIUM TAKING INTO ACCOUNT THERMOCHEMICAL INTERACTIONS BETWEEN PHASES

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The paper discusses the features of mathematical modeling of the process of oil displacement from a porous reservoir using thermochemical methods of enhanced oil recovery. An advantage of these methods is the following: as a result of an exothermic chemical reaction between the fluids, the oil temperature rises and the viscosity decreases, as a result of which the displacement process is accelerated.
One of the main difficulties in modeling multiphase seepage is the instability of the interface between liquids. In the case when a more viscous fluid is displaced by a less viscous one, initially flat interface is destroyed, the tongues of the displacing fluid break through the layer of the displaced; this phenomenon is called the Saffman-Taylor instability. In this case, the contact area between the phases increases, which affects the rate of the chemical reaction.
The paper discusses the results of a three-dimensional numerical simulation of the displacement of a viscous fluid from a porous medium. Experiments to displace the oil model with water from samples of Neocomian sandstones are also described. Comparison of the results of numerical simulation with experimental data is given. The possibility of determining unknown empirical constants of the mathematical model on an experimental basis is shown. A description of the method for calculating the area of the interphase boundary for such calculations is given, which makes it possible to observe the evolution of the contact area of the phases in the process of displacement.
The paper also proposes a mathematical model for describing the process of oil displacement using the thermogas method, which is characterized by the injection into the formation, as a displacing agent, of a heated mixture of gas and water. The gas considered in the work is a mixture of N_2, O_2, CO_2 and water vapor H_2O (*g*). Heated oxygen reacts with hydrocarbon, resulting in its oxidation with the release of heat; carbon dioxide and water vapor are formed. A method is proposed to take into account the blurring of the displacement front due to instability by introducing additional terms in the equations, which are determined from studies of the evolution of the phase contact area in three-dimensional modeling.
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SIMPLE MASS-SPRING MODEL TO ADDRESS DYNAMIC FRACTURE EFFECTS

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Dynamic fracture phenomenon is known to be characterized by effects which go beyond classic static strength concepts and thus static fracture models can potentially yield erroneous results. Dependence of the system strength on the loading rate and fracture delay are among these effects. In this work these effects are studied using simple linear oscillator model which is then calibrated to fit experimental results on dynamic crack initiation. The linear oscillator failure studies can be also useful for development of the earthquake protective systems which use fracture to reduce the wave energy.

DETERMINATION OF ACOUSTIC CAVITATION THRESHOLDS DEPENDING ON ACOUSTIC WAVE FREQUENCIES

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In the communication, we will analyze the changes in the threshold characteristics of acoustic cavitation of a liquid on the example of water depending on the oscillation frequency of acoustic field, hydrostatic pressure and temperature of a liquid. The calculation of these dependences will be presented on the basis of the incubation time criterion of cavitation, the classical Blake criterion for the unstable cavitation threshold and the classical nucleation theory. The main idea of the work is to study the possibility for applying the approach of the fracture incubation time of solids to the assessment of the dynamic strength of a liquid. It will be shown that the incubation time criterion makes it possible to analyze the threshold pressure of unstable cavitation without directly taking into account the parameters of the defective microstructure of the liquid. In turn, the classical criteria do not allow qualitatively modelling the considered dependences. Additionally, it will be discussed a possible relationship between the parameters of the considered approaches. This relationship can be used in the future for direct calculation of the parameters of the incubation time criterion of cavitation.

DETERMINISTIC AND STOCHASTIC PROCESSES IN A ONE DIMENSIONAL QUASICONTINUUM

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In this work the aspects of deterministic and stochastic processes in a one-dimensional quasicontinuum corresponding to the Hookean chain are considered. The term "Hookean chain" refers to a one-dimensional harmonic crystal with nearest-neighbor interaction (the term is introduced by A. Krivtsov [1]). The term "quasicontinuum" is to be understood as a concept of a continuous medium that corresponds to a chosen discrete medium, so that these media can be described within the scope of a unified mathematical formalism (was introduced by I. Kunin [2]).

One of the first detailed studies of one-dimensional harmonic crystal was presented by E. Schrödinger in 1914 [3]. It allowed a straightforward analytical analysis of motion in the system and revealed several important features, such as (a) for sufficiently small values of the parameter that determines the equilibrium interatomic distance, the process is approximately described by the wave equation; (b) an arbitrary initial impulse composed even of predominantly long-wave components will undergo a decay at sufficiently long times; (c) the character of of the displacement field evolution described by the fundamental solution is qualitatively more similar to the process of thermal conductivity rather than to classical wave propagation. These peculiarities play a key role in the processes of heat conduction in solid crystals and are crucial to build theories of heat transfer that use the concept of quasiparticles associated with atomic vibrations.

The pioneering works of G. Klein and I. Prigogine [4], C. Hemmer [5] shed light on stochastic processes in this system out of equilibrium. The deterministic Schrödinger solution was studied with stochastic initial conditions. The relations describing time evolution of second moments of velocities and displacements and their covariances were obtained. They describe the energy transfer in the system. These are the functions of time and particle index. "However, the apparatus of discrete mathematics is the most cumbersome therefore we shall also use the mathematical model of quasicontinuum for an adequate description of the discrete medium." ([2], p. 3)

In this paper, we consider a particular case of a quasi-continuum corresponding to a Hookean chain. The characteristic features are illustrated by the examples of particular initial conditions. The asymptotics of the front is considered. The quasi-continuum approach is generalized to stochastic problems and an equation describing the dynamics of the kinetic temperature field in the quasi-continuum is derived. It contains one additional parameter of the dimension of length - the interatomic distance. It is shown that in the limit when the interatomic distance approaches zero, the so-called ballistic equation is obtained. It was first derived earlier by A. Krivtsov using covariance analysis [4]. This transition illustrates that some peculiarities observed from comparison of kinetic temperature fields obtained from the ballistic heat equation [6] and discrete relations from [4,5] are due to the former theory being local and the latter being non-local.

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MODIFICATION OF THE LAGRANGE MULTIPLIER METHOD WITH A DETACHED CONTACT BOUNDARY FOR MODELING BODIES INTERACTION

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Two-dimensional elastic contact problem is considered. A modification of the Lagrange multipliers method with detached contact boundary is developed. The proposed approach allows one to construct the Lagrange multiplier function approximation indifferent to meshes inside contacting bodies. It also gives a possibility to construct contact boundary as smooth as it needed for solution accuracy. Besides, an opportunity to use various functions for approximation of the Lagrange multipliers function is appeared. A discontinuous piecewise constant approximation of the Lagrange multipliers function is considered. The test problems for the two bars system with varying complexity contact boundaries are solved. The performed test calculations showed satisfactory results. Nevertheless, there are artificial oscillations of the normal stress at the contact boundary. The possibility of refining the solution by discretizing the contact boundary and increasing the number of Lagrange multipliers is presented.

ON REPRESENTING STOCHASTIC EXCITATIONS BY DETERMINISTIC ONES FOR INTERPRETING THE STOCHASTIC RESONANCE PHENOMENON

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Adding noise to a system can "improve" its dynamic behaviour, for example increase its response or signal-to-noise ratio. The corresponding phenomenon, called stochastic resonance, has found numerous applications in physics, neuroscience, biology, medicine, and mechanics. Replacing stochastic excitations by high-frequency ones was shown to be a viable approach to analyse the stochastic resonance phenomenon in several linear and nonlinear dynamic systems. For these systems the influence of the stochastic and high-frequency excitations appears to be qualitatively similar. The present paper concerns the discussion of the applicability of this "deterministic" approach to various stochastic systems. First, the conventional nonlinear bi-stable system exhibiting the stochastic resonance phenomenon is briefly revisited. Then linear dynamic systems with multiplicative noise are considered and the validity of replacing stochastic excitations by deterministic ones for such systems is discussed. Finally, we study oscillatory systems with nonlinear damping and analyse the effects of stochastic and deterministic excitations on such systems.

COMPUTER SIMULATION OF THE COMBUSTION CHAMBER OF HYBRID ENGINE

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In this work hybrid engines are systems that use fuel and oxidizer in different aggregation states. Solid state Hydroxyl-terminated polybutadiene (HTPB) type fuel and gaseous oxidant were used. Such engines offer advantages over classical solid fuel and liquid engines. In this work unsteady processes occurring in the model combustion chamber of a such hybrid solid-fuel engine in a three-dimensional formulation were studied using computer simulation. Part of the combustion chamber is made of HTPB. The oxidizer enters in the chamber with a supersonic speed and interacts with a solid fuel. The last one begins to heat up and combustible gas (butadiene) emit into the chamber. Two models of the regression of the fuel were considered. One of them was based on semi-analytic expressions obtained within the frame of the boundary layer approximation. The second model used the numerical results of calculations from turbulent model. A special software package was developed for this calculations. Calculations of chemical reactions were carried out by solving the stiff system of chemical kinetics with using the fourth-order semi-implicit Novikov method from the Rosenbrock family of methods with double calculation of the right-hand side of the system and one-time calculation of the Jacobian. The MUSCL method for interpolating flows onto the face and the AUSMP method for compression terms were used for simulation of gas-dynamic processes. MacCormack method was used to advancement to the second order of accuracy. The k-ω Wilcox turbulence model was used to simulate the influence of turbulence. A different geometry of combustion chamber and solid fuel were considered. The distributions of the value of parameters in the combustion chamber were established. The compare result of regression rate of solid fuel with experiments data was done. The influence of the coefficients of the kinetic mechanism on the processes occurring in the chamber was studied. The unsteady nature of the occurring in camera processes is obtained. The significant influence of kinetics on the process of

ignition of fuel vapors was shown.
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DEPENDENCE OF THE DISPERSION CURVES OF POCHHAMMER-CHREE WAVES ON THE ELASTIC MODULUS AND GEOMETRY OF A HOLLOW CYLINDER

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The paper uses analytical expressions describing the propagation of Pochhammer-Chree waves in an infinite elastic hollow cylinder. Dispersion curves are constructed based on numerical solutions of the dispersion equation. The influence of the ratio of the outer and inner diameters of a hollow cylinder and its elastic modulus on the dispersion curves of Pochhammer-Chree waves is analyzed.

COMPARATIVE ANALYSIS OF ENERGY ABSORPTION AND DEFORMATIONS OF METALLIC TUBES WITH DIFFERENT CONFIGURATIONS UNDER AXIAL IMPACT

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The finite element simulations were carried out using ABAQUS/Explicit solver to study the energy absorption and deformation behavior of metallic tubes with different configurations under different axial loading conditions. The thin walled mild steel tubes of square and circular sections were subjected to quasi-static and dynamic loading condition. A comparative study is carried out on energy absorption behavior of single tube and multi tubes with equivalent sectional area under the identical loading conditions. The material flow and damage behavior of the tubes were simulated using the Johnson-Cook material model. The axial crushing of the mild steel tubes has been found higher under quasi-static loading in comparison to dynamic loading conditions for same kinetic energy. In general, the absorbed energy was found higher in circular tube as compared to that in square tube of equivalent section under axial impact.

BENDING A BEAM MADE OF MATERIAL WITH STRAIN STATE DEPENDENT PROPERTIES

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The mechanical properties of many materials, such as concrete, cast iron, and rocks, depend on the type of strain state. Usually, it is true for materials with inhomogeneous structure. It is expressed in the absence of unified diagrams of the relationship between stress and strain intensity for various types of stress state. This is most noticeably manifested in the dependence of shear and volume deformation processes. Volumetric deformations can occur under shear conditions. Such materials may be described by constitutive relationships depending on the parameter of the type of strain state, which is the ratio of the first invariant of the strain tensor to the strain intensity. A special type of constitutive equation which take into consideration strain state were introduced. Bending of a beam made of such material was studied using FEM. The results of calculation demonstrate the difference relatively to linear model. Also, it is shown, that stress and strain states differ along the length of the beam.

STRESS-STRAIN STATE OF T-SHAPED JOINT OF THIN-WALLED ELASTIC PIPES

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The T-shaped intersection of thin-walled cylindrical pipes is a stress concentrator. The rod mathematical model of this construction is not detailed enough to study such stress field. We propose a mathematical model of this mechanical system as a curvilinear shell immersed in a three-dimensional Euclidean space. Force and geometric conjugation conditions are imposed on the pipe joint line. The restrictions on the parameters of the mathematical model are found, the ranges of parameter values are established, within which the model remains applicable. The symmetry properties of this model are studied. Based on the properties of symmetry, the differential equations of the mathematical model are

formulated in the global Cartesian coordinate system. A reduced statement of the boundary value problem for only two independent variables is formulated. Thus, the dimension of the original problem is reduced by one. After changing the type of boundary conditions, the conjugation conditions were removed from the problem statement. The two-dimensional boundary value problem is split into two sub-problems in rectangular domains. Numerical experiments are performed to confirm the adequacy of the mathematical model. The correctness of the proposed replacement of the type of boundary conditions is established. The existence and character of the stress field singularity are revealed by two different numerical methods. The work has been supported by the Russian Science Foundation grant № 21-11-00039, https://rscf.ru/en/project/21-11-00039/.

ATTRACTION BASIN FOR THE GENERALIZED KAPITSA'S PROBLEM OF STABILITY OF INVERTED PENDULUM

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The problem of stability of inverted pendulum referred to as Kapitsa's pendulum belongs to the class of the problems of mechanics, in which vibration completely changes the behavior of the system. In the classical formulation, the dynamics and stability of an inverted mathematical pendulum with a supported lower end vibrating in the vertical direction in a gravity field is investigated. In this paper, various generalizations of the Kapitsa's pendulum problem are considered for the case of a flexible inextensible and flexible tensile rod under the action of harmonic and random oscillations of the lower end and for various sorts of the lower end fixation. The conditions for the stability of the upper vertical equilibrium position are found. The attraction basin of the upper equilibrium position is found depending on the initial conditions for the cases when the upper position is stable. The problem has a small parameter equal to the ratio of the amplitude of the oscillations (or the mathematical expectation of the amplitude in the case of random excitation) and the pendulum length. The solution is sought by means of the asymptotic integration method.
The research was carried out in the framework of projects 19.01.00280-a, 20-51-S52001 МНТ-а of the Russian Foundation for Basic Research.

PELTIER ELEMENT MODEL WITH TEMPERATURE-DEPENDENT MATERIALS

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Peltier element model, based on analogy between electrical and thermal fields, is considered. Analytical expressions for stationary thermoelectric problem in the case of temperature-dependent materials is given. A compact model for thermoelectrical model with temperature-dependent parameters is presented. Expressions for heat fluxed on the emitting and absorbing sides with a dependence on the boundary temperature values and applied current are obtained. It is shown that the taking into account the dependence of the material on the temperature makes it possible to achieve a higher level of the temperature on the cooling side in comparison to the model with average material parameters. The analysis and comparison of the numerical values of heat fluxes and temperatures on the hot and cold sides obtained using the analytical model of the Peltier element with the finite element model constructed in the ANSYS software package have been carried out.

DESCRIPTION OF THE MECHANICAL PROPERTIES OF THE GRAPHYNE BASED ON THE PAIR INTERACTION POTENTIALS

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The article deals with the model of allotropic modifications of the graphyne. The structures have a similar geometric structure, in this regard, a general stiffness tensor for the 6-6-12 graphyne is compiled. As special cases are considered graphene, γ-graphyne, "6,6,12"graphyne, β-graphyne, α-graphyne. The model is a two-dimensional structure, the atoms of which are connected by beams. The beams, in turn, have transverse and longitudinal stiffness. Through a set of these microparameters, in some cases there are different numbers of stiffnesses, the components of the stiffness tensor of the fourth rank are determined. Stiffness tensors were constructed, which are expressed in terms of lattice microparameters. The model under study is a sheet of graphyne with a thickness of one atom. Microscopic characteristics are of great

interest. With their help, it is possible to predict the behavior of the material under tension/compression. To determine them, data were taken[1]. After drawing up the minimizing functional, microparameters were selected using nonlinear optimization methods .Stable equilibrium conditions - constraints under which the functional was minimized.Positive definiteness of tensors of the second and fourth rank is necessary[2]. To find the parameters more correctly, the degree of the terms of the minimizing functional varies, which allows you to expand the extremum zone. Also, we study the distances of functions that depend on microparameters in C^n spaces. This is done in order to estimate the difference between the found microparameters, i.e. knowing the final difference between Young's modulus or Poisson's coefficients between different materials, you can give an estimate for the discrepancy of microparameters. The space C^n was chosen as the most convenient metric expression.

On the basis of the found microparameters, the interaction potential of γ - graphyne is calculated.The potential for the two directions was constructed differently, which takes into account the anisotropy of the material. We used the fact that the second derivative is exactly equal to the bond stiffness in this section. The potential is a piecewise given function. The first section shows the deformation with positive rigidity, on the second the function becomes convex downwards, which indicates a change in the sign and a break in the bonds.Further, it is assumed that the potential forces and forces are expressed in terms of the potential gradient. To determine the cutoff radius (the distance at which the interaction is nullified), the linear law of the relationship between the stress and strain tensors is used.Qualitatively, after finding the microparameters, the location of a possible connection break is estimated.Numerical dependences of stresses and deformations were obtained quantitatively (by iterative method), which were compared with the work[3]. The critical stresses and deformations are estimated. The considered values are compiled for γ - graphyne, but with the help of the found microparameters and the compilation of the paired interaction potential, it is possible to predict the behavior of other modifications and evaluate their stress-strain state.

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INVESTIGATION OF THE LOW-FREQUENCY ELECTRICAL EFFECT ON THE EMULSION IN THE PRESENCE OF CONVECTIVE FLOWS

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The usage of electrostatic energy is considered one of the most effective methods of separating emulsions. One of the main advantages of this method is low power consumption. The interaction of the electromagnetic field with oil dispersed systems showed that in addition to the thermal effect, destructive forces appear. They manifest themselves at the micro-and nanoscale. There is a mechanical effect on the emulsion, the destruction of the structural and mechanical barrier. The paper [1] presents the results of experimental and numerical studies of the high-frequency and ultrahigh-frequency effects of electromagnetic fields on oil-water emulsions. It is shown that under electromagnetic and thermal effects on the emulsions, they are heated and their viscosity decreases, after which the process of coagulation of the emulsion drops becomes more intense, the drops settle down faster. The study of low-frequency effects on emulsion systems in the presence of convective flows can be applied to the separation of emulsions, for example, in the oil industry.

In this paper, laboratory studies were conducted to study the effect of low-frequency exposure on the dynamics of the movement of emulsion systems in a convective cell. An experimental setup was assembled, the main part of which is a cell, with the possibility of heating the upper and lower faces and ITO glasses on the sides with etched electrodes. The dimensions of the inner cavity are 50x50x12mm. The electric field is generated by an Agilent 33522 signal generator and then amplified via a Tabor 9100 amplifier. The electrode system provides a highly inhomogeneous field in the cell. Heating and cooling of the emulsion system was carried out using aluminum tubes of rectangular cross-section 12x12 mm, which were installed in the cell from the bottom and top. The experimental area of the cell was recorded on the camera. The cell was illuminated using a Sumita LS-M250 light source.

As a result of the influence of an inhomogeneous electric field, the drops of the emulsion gather in the region with the maximum intensity, thereby provoking the coalescence of the drops. Convective flows can create mixing in the volume of the emulsion and also provoke a collision, which can be positive for the task of separating the emulsion.

The reported study was funded by the grant of the Russian Science Foundation (project №19-11- 00298).

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MODELIZATION AND PROCESSING OF MOTOR CORTEX EEG SIGNALS FOR BIOMECHANICAL APPLICATIONS

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The task of the work is to extract the EEG picture of motor activity and movement for signals of imaginary and real movement.
Biomechanics development can widely implement motor cortex neurocontrol systems.
In this scientific paper, we will go step by step to discover our brain activities. We will use different tools and algorithms capable of mastering the high level of complexity of the brain signals.
The project consists of several sections: recording an array of data using EEG equipment with a selected recording protocol, primary processing and filtering of data, analysis of the processed electroencephalogram, mapping the active zones of the brain using specialized software, and group analysis of the results of the subjects who took part in the experiment.
This research is the first step in mastering the tasks of neurocontrol using the interpretation of the EEG of the motor cortex. The complexity of the work lies in the approach - the signals of the motor cortex are difficult to interpret, and in the equipment used - can be called rather amateur than medical or professional, which complicates the experiment, but gives hope for the rapid development of the neurocontrol industry firstly because of the cheapness of research.

ANALYTICAL MODEL FOR ANALYSIS OF NANOINDENTATION OF THIN COATINGS

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Indentation of an elastic isotropic coated half-space by a rigid punch is considered. The coating is assumed to be homogeneous, layered or functionally-graded. The contact problem is reduced to the solution of a dual integral equation. A kernel transform of the integral equation is approximated by a ratio of two polynomials taking into account its asymptotic behavior. The solution of the integral equation with the approximated kernel transform was constructed analytically using the bilateral asymptotic method. Analytical expressions for the distribution of the contact stresses, indentation force, depth, stiffness and contact radius are obtained. Simplified expressions for these quantities are also proposed based on the simplest one-parametric approximation of the kernel transform. The analysis of the accuracy of the obtained solutions is made depending on the value of dimensionless coating thickness and ratio of the effective elastic moduli of the coating and the substrate. The difference between the contact characteristics for the coated and non-coated materials are analyzed in details. Correlation of the theoretical and experimental results is also discussed.
This work was supported by the Government of the Russian Federation (grant No. 14.Z50.31.0046).

NEW MECHANISM OF THE ONSET OF AEROELASTIC DIVERGENCE

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There are two types of aeroelastic instabilities: divergence and flutter. Flutter is an oscillatory loss of stability, whereas transition to divergence occurs at zero frequency; that is, it is a static instability. A general divergence mechanism described in textbooks consists of a decrease of one of the natural frequencies down to zero due to negative aerodynamic stiffness, coalescence with its paired frequency, and (after the coalescence) transformation to one damped and one growing frequency [1-3]. Most examples of this mechanism use quasi-steady aerodynamics that, at first sight, is suitable for divergence analyses because of its static nature.
In this study, it is shown that, when using unsteady aerodynamics (Theodorsen theory), the analytical structure of eigenfrequencies essentially changes; namely, no frequency coalescence occurs but “structural” eigenfrequencies become damped [4]. The divergence mode is not a continuation of a natural mode, but it separates from a continuous spectrum that exists in the aeroelastic system due to the wake behind the wing when unsteady aerodynamics is used but is absent in the quasi-steady case.

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EVALUATION OF BIOMECHANICAL CHARACTERISTICS OF THE EYE AFTER SURGICAL HYPEROPIA CORRECTION

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Evaluation of changes in the elastic properties of the eye after laser vision correction is an important and urgent problem. The biomechanical properties of the eye affect the intraocular pressure measurements obtained by various tonometers in clinical practice. In present study a mathematical model of measuring of the intraocular pressure by Maklakoff tonometer is presented. The elastotonometry method is used to assess biomechanical properties of the eye in treatment of hyperopia with LASIK and FemtoLASIK surgeries. The eyeball is represented as two joint segments (the cornea and the sclera) of different geometric and mechanical properties loaded with internal pressure. Finite element simulation is performed by means of the engineering simulation software ANSYS Inc. As a result of consecutive measurements of the intraocular pressure with Maklakoff tonometer (wide flat stamps weighing 5; 7.5; 10 and 15 g) the dependence curve of tonometric intraocular pressure vs. tonometer weight is plotted and analyzed for two laser correction procedures.
The research was carried out in the framework of projects 19.01.00280-a of the Russian Foundation for Basic Research.

FUNDAMENTAL EDGE WAVES IN A PLATE WITH ASYMMETRIC NON-RECTANGULAR EDGE PROFILE

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Elastic waves guided by the edge of a plate or a shell (edge waves) are thoroughly studied for the case of a straight edge formed by a cross-section perpendicular to the faces of the plate. But in the practical applications it is possible, that the edge of a real plate does not meet this requirement of the ideal form. In this talk, the influence of a small imperfectness of the edge profile on the dispersion properties of fundamental edge waves is investigated. The plates with the edges characterized by facets with rounded wedges and a small deviation of the cross-section from the perpendicular one are considered. The vibrations of the plate are described by 3D equations of elastodynamics. The semi-analytical method based on the modal expansion is employed to obtain the solution of the boundary value problem for the plate with loading, in which the edge waves correspond to the poles. It is shown that the small deviations of the edge profile from the ideal rectangular form strongly affect the slowness-frequency dependence of the symmetric fundamental wave. The asymmetry of the profile leads to the coupling of symmetric and antisymmetric motions, which results in the small attenuation of the symmetric edge wave. The dependence of this attenuation from the angle of inclination is investigated. Comparison with the experimental dispersion curves obtained from the data measured by the laser Doppler vibrometry on 5 mm-thick aluminium plate are presented.
The reported study was funded by RFBR, project number 20-01-00673.

CYLINDER INDENTATION INTO A VISCOELASTIC LAYER TAKING INTO ACCOUNT THE SURFACE MICRORELIEF

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The indentation of a rigid cylinder into a viscoelastic layer lying on a rigid base under the action of a constant load is considered. The cylinder has a flat, rough base of a given radius. The roughness is modeled by a system of identical axisymmetric asperities evenly spaced with a given density on the contacting surface of the cylinder. Two scale levels of the considered contact problem are considered. The micro-level is the scale of a single contact spot. At this scale level, the solution of the periodic contact problem is used to determine the dependencies of the contact characteristics on time (the size of a single contact spot, the real contact pressure distribution and the dependence of the additional displacement of the rough layer on the nominal pressure). The macro-level is the scale of the nominal contact region (the radius of the cylinder base). This approach is a generalization of the method developed in [1] for solving the problems of indenting rigid rough bodies into an elastic layer or an elastic half-space. The dependence of the additional displacement function on the nominal pressure obtained by solving the periodic contact problem at the micro-level [2] is used to formulate the contact condition at the macro-level. The dependence of the contact pressure on the displacement of the layer boundary is assumed to be linear, which is valid for thin layers (small thickness relative to the radius of the cylinder).
The approach used to solve the problem allows us to calculate the dependence of the penetration depth on time, taking into account the microrelief of the cylinder surface. To describe the mechanical behavior of the layer, the standard viscoelastic solid model is used. The influence of the shape of the asperities and their spatial location on the cylinder penetration depth is investigated. The influence of the layer thickness and the viscoelastic properties of the material (the ratio of creep and relaxation times of the viscoelastic model) on the penetration-time function is also analyzed. Additionally, the effect of the microrelief parameters on the real contact area is investigated.
The research is supported by the Russian Science Foundation (project 18-19-00574).
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DETERMINATION OF THE EFFECTIVE SURFACE TENSION AT THE INTERFACE IN WATER-IN-OIL EMULSION USING AFM

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The fluid extracted from an oil reservoir is most often a water-in-oil emulsion. Water droplets in such emulsions are surrounded by a stabilizing shell consisting of polar oil components [1]. This shell prevents the coalescence of the droplets and makes water-in-oil emulsions extremely resistant to external influences [2].
In the present work, the method of determining the effective surface tension at the interface between a water droplet with a stabilizing shell and a hydrocarbon liquid using the force spectroscopy method on an atomic force microscope (AFM) is proposed.
In the experiments, droplets with molecules of solid hydrocarbons - asphaltenes adsorbed on the surface, extracted from the prepared stable model water-in-oil emulsion, were studied. The experiments were performed for emulsion droplets of different diameters ranging 30-100 μm.
The droplets were placed in a specially designed liquid cell filled with tetradecane, which was a plastic ring fixed on a slide. The experimental study was performed on Agilent 5500AFM, using a CP-CONT-Au silicon cantilever without an attached ball.
As a result of the experiment on nanoindentation of droplets, time dependences of the distance by which the scanner with the cantilever is moved and the voltage appearing on the photodetector as a result of deflection of the cantilever beam were obtained.
During the processing of the experimental curves, only the approach section was investigated from the moment the cantilever began to interact with the sample. The coefficient for recalculation of the voltage in the deflection was determined using a curve plotted on an absolutely elastic surface, on which the cantilever beam deflection is directly proportional to the AFM scanner's displacement. In the experiment, it is assumed that when a spherical-shaped drop is pressed, it acquires an elliptical geometry. The cantilever indentation depth can be calculated as the difference between

the scanner displacement and the cantilever deflection. This makes it possible to determine the geometric parameters of the ellipsoid depending on the indentation depth. The force constant provided by the cantilever manufacturer is used to recalculate the deflection into an indentation force.
Then, based on the theory of thin films [3], the dependences of effective surface tension on time were plotted. By interpolating the curves, the effective surface tension of unperturbed emulsion water droplets covered with a stabilizing shell was determined. Specifically, for a drop with a diameter of 80 μm, the effective surface tension was 0.00173 N/m.
The work was done in the laboratories of the Center of Micro- and Nanoscale Dynamics of Disperse Systems, created within the framework of a megagrant of the Ministry of Education and Science of Russia (11.G34.31.0040).

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MODELLING FLUID FLOW THROUGH A FLEXIBLE VESSEL WITH ELASTIC WALLS

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We exploit a two-dimensional model [1], [2] and [3] describing the elastic behavior of the wall of a flexible blood vessel which takes interaction with surrounding muscle tissue and the 3D fluid flow into account. We consider the linear non-stationary Stokes equations simulating a heartbeat,
we study time-periodic solutions in a straight infinite cylinder with an arbitrary cross-section.
In the case of the Dirichlet (no-slip) condition, according to well-known results, there are many periodic solutions (**v**, p), where the velocity **v** has only the component directed along the cylinder (z-axis) and the pressure p depends linear on z with coefficients depending only on the time variable
t. For elastic walls, there is only one such solution up to a constant factor, proportional to the steady Poiseuille flow which does not depend on the time variable but can be considered as periodic one with any period. This is precisely the difference in behaviour of blood flow between elastic and
rigid walls. The former smooths (at removal from the heart) the blood flow entering the aorta, and then into the artery with sharp, clearly defined jerks, this is how the heart works with a heart valve, and the latter reproduce the frequency of the flow throughout the length of the pipe.
Due to the elastic walls of arteries, an increased heart rate only leads to an increase in the speed of blood flow (the flux grows) without changing the structure of the flow as a whole, and only at an ultra-high beat rate, when the wall elasticity is not enough to compensate for the flow pulsation, the
body begins to feel heart beating. The fact is that the human arterial system is geometrically arranged in a very complex system, gently conical shape of blood vessels, their curvature and a considerable number of bifurcation nodes. Therefore, the considered model problem of an infinite straight cylinder gives only a basic approximation to the real circulatory system and on some of its elongated fragments, which acquires periodic disturbances found in the wrists, temples, neck and other periphery of the circulatory system. The correctness of such views is also confirmed by a full-scale experiment on watering the garden: a piston pump delivers water with shocks, but with a long soft hose the water jet at the outlet is unchanged, but with a hard short-pulsating one.
Compared with the classical works of J.R. Womersley our formulation of problem [4] has much in common. In Wormerley’s works, axisymmetric pulsative blood flow in a vessel with circular isotropic elastic wall is found as a perturbation of the steady Poisseulle flow. Apart from inessential generalizations like arbitrary shape of vessel’s cross-section and orthotropic wall, the main difference of our work is in the coefficient K(s) which describes the reaction of the surrounding cell material on deformation of the wall. In other words, the vessel is assumed in Womersley’s works to "hang in air" while in our model it is placed inside the muscular arteria’s bed as in human and animal bodies intended to compensate for external and internal influences.

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NONLINEAR DYNAMICS OF DISK-BASED MEMS CORIOLIS VIBRATING GYROSCOPE UNDER PARAMETRIC EXCITATION OF VIBRATIONS

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This work is devoted to the development of a mathematical model and qualitative nonlinear dynamics of MEMS Coriolis Vibrating Gyroscope (CVG) with a volume disk resonator in the free precession mode of oscillations with parametric excitation of the resonator.
The presented CVG operates in the whole angle mechanization. In such devices, vibrations are freely transmitted between orthogonal modes due to the Coriolis force, which leads to precession of the vibration mode of the resonator mounted on the movable base. The orientation of the axis of the precession angle makes it possible to measure the angle of rotation relative to the inertial coordinate system.
Nonlinear equations of the dynamics of a resonator on a movable base are obtained. The nonlinear dynamics of the system is investigated in the region of the main parametric resonance.
For the parameters of a possible assessment of the CVG design, starting voltages were performed. Resonance curves are constructed using asymptotic methods, and the stability of the obtained stationary solutions is investigated.
The proposed dynamic model of CVG in the future will be a model for the development of algorithms for carrying out calibration tests of the sensor in the presence of material and geometric elements, balancing methods and control algorithms for an oscillatory sensitive element.
A method is proposed for the qualitative study of the regime of free precession in systems of the Foucault pendulum, based on the numerical methods of the theory of continuation and bifurcations.

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